The MagPi

Issue 99 | November 2020 | magpi.cc

The official Raspberry Pi magazine

RASPBERRY PI

2020's HOTTEST GADGETS

ULTIMATE WISHLIST

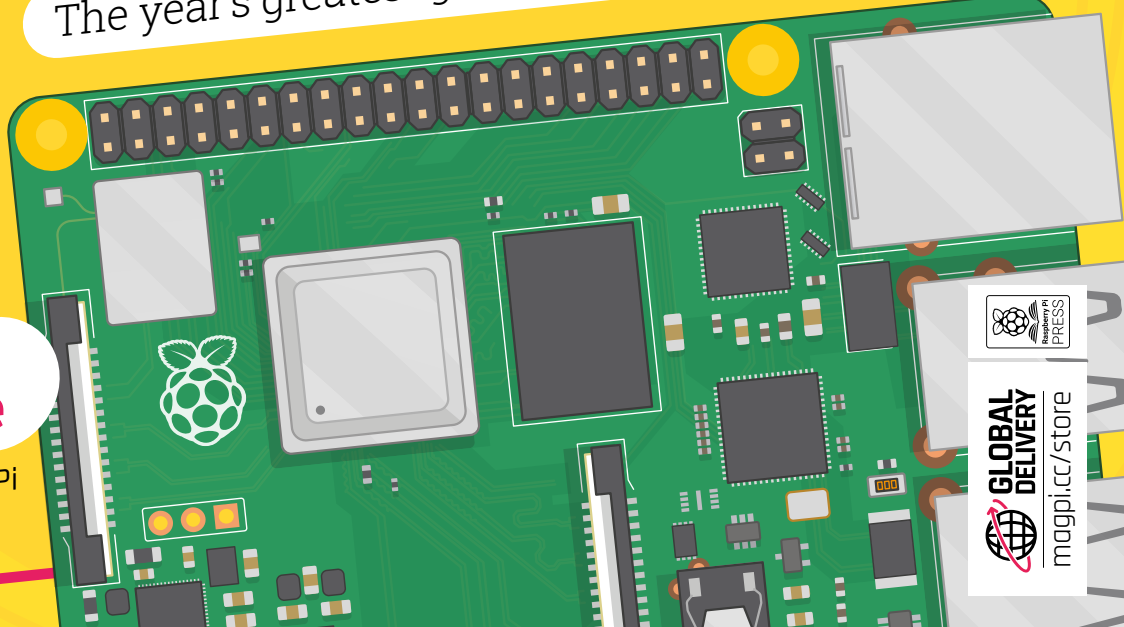Robots & automation

Sound & vision kit

Gaming gadgets

The year's greatest gear - essential kit you must own!

Christmas **comes early!**

Get Raspberry Pi-ready for the festive season

Build a retro **CD-ROM console**

Attach a disc drive to Raspberry Pi and load up classic games

MAKE YOUR OWN RASPBERRY PI **HOME ASSISTANT**

WELCOME
to *The MagPi* 99

Computing is a magical hobby. With a low-cost computer like Raspberry Pi, you get hours upon hours of entertainment from just five dollars.

You can learn an ample amount with just a Raspberry Pi and a good resource, like this copy of *The MagPi* magazine you're holding. I can spend hours with a computer and a good book.

Throw a few more dollars down and Raspberry Pi can become just about anything: a robot for growing plants, a camera that takes 3D photographs, or an arcade machine from the 1980s.

All you need is a smidgen of inspiration and, in some cases, a bit more kit. Often not much, and typically not that expensive.

Our Raspberry Pi Ultimate Wishlist (page 41) has a wild amount of extra equipment to buy – everything a budding maker could dream of. There's so much inspiration in this issue, you're bound to find something to build.

Money can't buy you love, but it can buy new computer equipment. And we love making stuff with Raspberry Pi, so it all works out in the end.

Have fun with this issue, and I hope you get something fun to make with Raspberry Pi.

Lucy Hattersley Editor

PS. Big 100 next month!

EDITOR

Lucy Hattersley

Lucy is editor of *The MagPi* and has just bought a Pret sandwich, a subscription to Film Stories, and a cinema ticket. 2020 hasn't been fun, but please look after the things you enjoy.

@LucyHattersley

GET A **RASPBERRY ZERO W KIT** WITH A SUBSCRIPTION! **PAGE 38**

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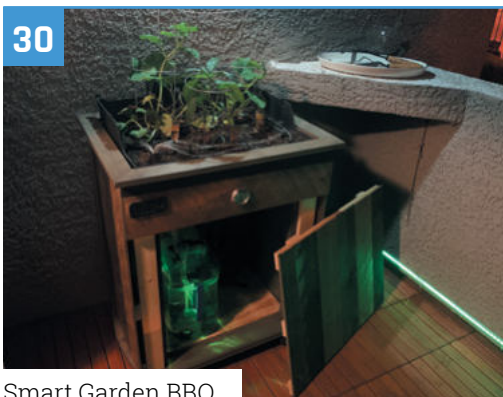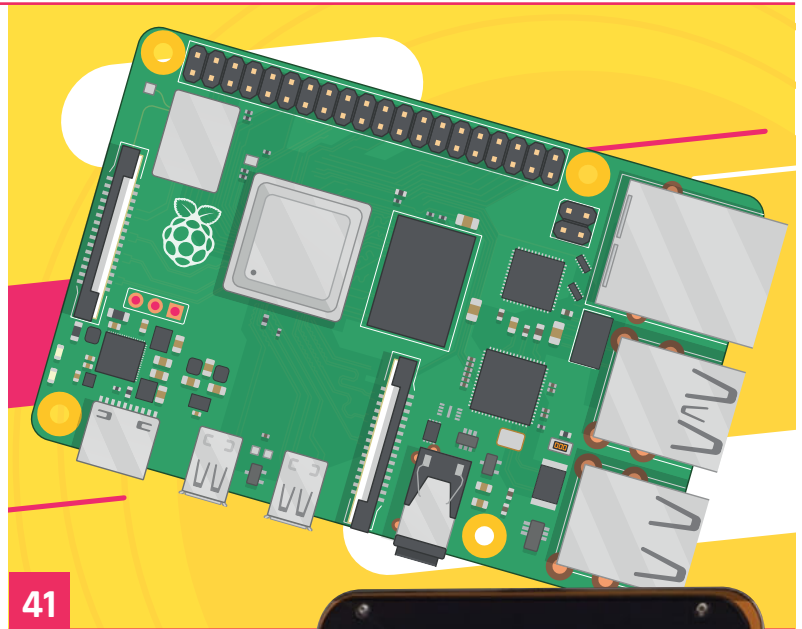
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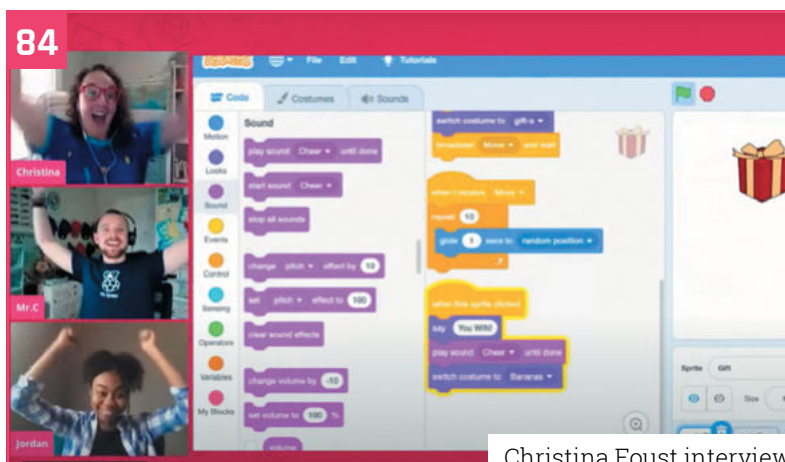
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Raspberry Pi
Compute Module 4

Raspberry Pi Compute Module 4 brings the latest technology to embedded devices. By **Gareth Halfacree**

The original Raspberry Pi Compute Module launched in April 2014 as a means to make it easier for engineers and professionals to put the power of Raspberry Pi into their designs. The compact Raspberry Pi Compute Module isn't a single-board computer but a system-on-module (SOM) designed to be inserted into a carrier board.

In 2016, Raspberry Pi Compute Module 3 and Compute Module 3 Lite offered higher specifications, switching to the same processor as Raspberry Pi 3. Compute Module 3+ boosted specifications still further.

And now Raspberry Pi Compute Module 4 and Compute Module 4 Lite make the jump to the same high-performance hardware as Raspberry Pi 4.

These are the most powerful Compute Modules ever made.

> ❝ These are the most powerful Compute Modules ever made ❞

PCI Express

Raspberry Pi Compute Module 4 makes the BCM2711C0's PCI Express lane available for any purpose. Depending on carrier board, the PCI Express lane can be used for high-bandwidth connections to USB devices, accelerator coprocessors, network devices, or high-speed Non-Volatile Memory Express (NVMe) storage – boosting storage throughput to around 390MB/s.

Raspberry Pi Compute Module 4 includes the same wireless LAN and Bluetooth radio as its full-size equivalent

The eMMC chip on the full Compute Module 4 replaces a microSD card as primary storage

An antenna can be added to this U.FL connector. Handy when Compute Module 4 is being used inside a metal case

The new high-density connectors on the underside break out more of the BCM2711C0's features than the old SODIMM connector

The BCM2711C0 system-on-chip boosts performance considerably over Raspberry Pi Compute Module 3's BCM2837

With up to 8GB of LPDDR4 memory, Raspberry Pi Compute Module 4 can handle more complex applications

Meet Raspberry Pi
Compute Module 4

Raspberry Pi Compute Module 4 takes on a new form factor, offering improved mountability

Raspberry Pi Compute Module 4 uses a new form factor, swapping the SODIMM edge connector of earlier models to two high-density connectors on the underside. It's a necessary change that brings all the features of the module to the carrier board.

This requires a change in the pins which connect the module to the carrier board. While both systems have 200 pins, the new connector is smaller and adds compatibility with new Raspberry Pi features, like the second HDMI port and PCI Express.

Sadly, this means Raspberry Pi Compute Module 4 isn't compatible with carrier boards designed for Raspberry Pi Compute Module 3.

The new SoC improves performance, the additional RAM makes it possible to work with more complex applications, and high-speed PCI Express connectivity means carrier boards have access to significantly more bandwidth.

Specifications

SOC: Broadcom BCM2711C0 quad-core ARM Cortex-A72 (ARMv8-A) 64-bit @ 1.5GHz

GPU: Broadcom VideoCore VI

RAM: 1GB, 2GB, 4GB, or 8GB LPDDR4 SDRAM

NETWORKING: 2.4 GHz and 5 GHz 802.11b/g/n/ac WLAN, Gigabit Ethernet PHY

BLUETOOTH: Bluetooth 5.0, Bluetooth Low Energy (BLE)

GPIO: Carrier board dependent

INTERFACES: PCI Express, 2× DSI, 2× CSI, 2× HDMI

STORAGE: External (CM4 Lite); on-board 8GB/16GB/32GB eMMC (CM4)

PORTS: Hirose U.FL antenna connector

DIMENSIONS: 55×40×4.5mm, 12g (excluding carrier board)

Benchmarking Raspberry Pi
Compute Module 4

Anyone upgrading from Raspberry Pi Compute Module 3 to 4 can expect a major performance boost

When Raspberry Pi 4 launched last year, it did so with the promise of a significant boost in performance over Raspberry Pi 4 thanks to a more powerful processor, brand-new graphics processing unit (GPU), up to four and now up to eight times the memory, and a number of other architectural changes. Now, Raspberry Pi Compute Module 4 brings those self-same improvements to designers building hardware powered by Raspberry Pi – and it doesn't disappoint, delivering beat-for-beat the same performance as Raspberry Pi 4.

> **❝** It doesn't disappoint, delivering beat-for-beat the same performance as Raspberry Pi 4 **❞**

Linpack

This version of the Linpack synthetic benchmark, ported to Raspberry Pi by Roy Longbottom, showcases peak performance gains in single-precision (SP), double-precision (DP), and NEON-accelerated. Here, Raspberry Pi Compute Module 4 delivers nearly five times the performance of the SoC powering Raspberry Pi 3 Model B and Raspberry Pi Compute Module 3+.
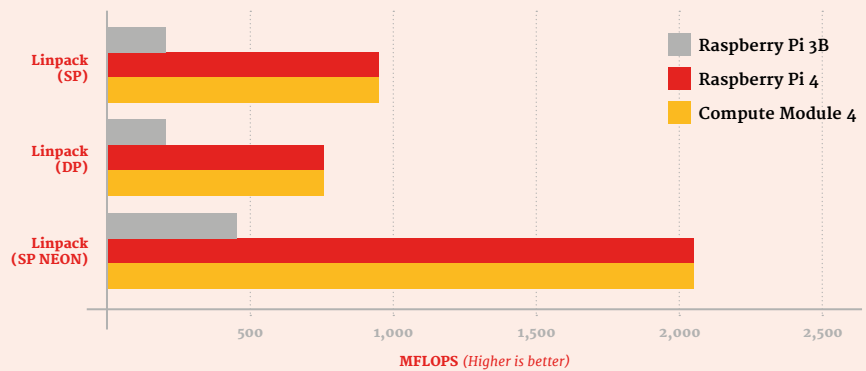
File Compression

An example of a real-world workload, this benchmark compresses a file using single- and multi-threaded versions of the bzip2 compression program. Here, Raspberry Pi Compute Module 4 is over twice as fast as the same benchmark running on Raspberry Pi 3 Model B or Raspberry Pi Compute Module 3+.
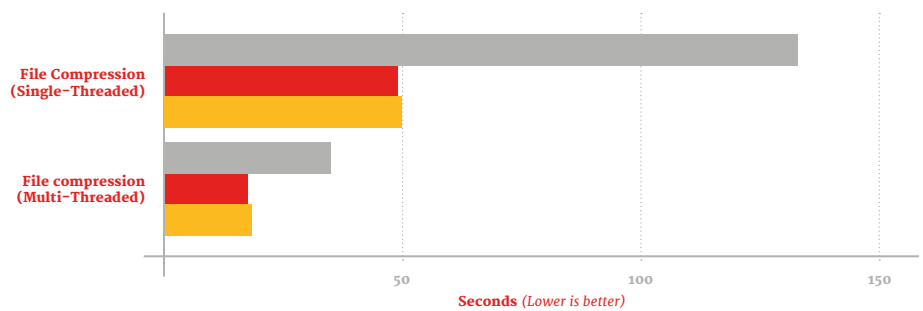
Speedometer 2.0

Designed to showcase performance in browser-based tasks, Speedometer 2.0 running in the Chromium browser on Raspberry Pi OS measures how quickly a web application responds. Here, Raspberry Pi Compute Module 4 is again over twice as fast as its immediate predecessor.
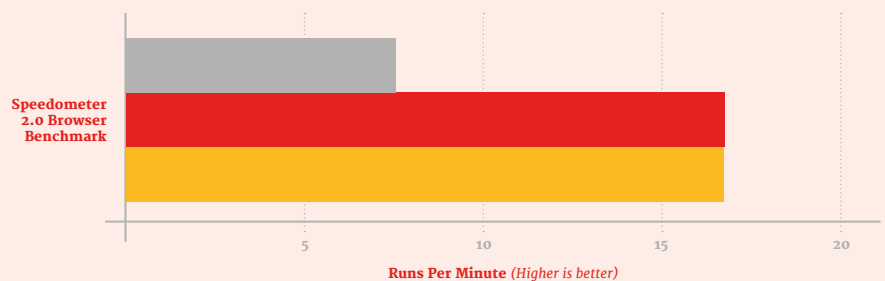
Image Editing

Another real-world test, this benchmark performs common image editing operations on a high-resolution picture and saves it into memory. The gains here are less, thanks to a reliance on memory performance over CPU performance – but Raspberry Pi Compute Module 4 still delivers a 73 percent improvement.

GIMP Image Editing

■ Raspberry Pi 3B
■ Raspberry Pi 4
■ Compute Module 4

Seconds *(Lower is better)*
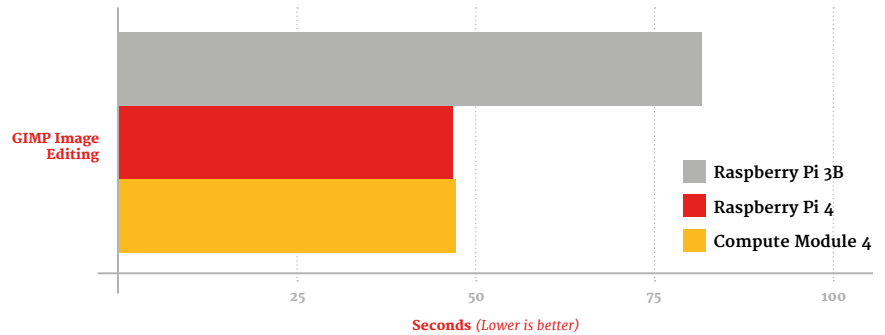
Storage Throughput

Having on-board eMMC storage isn't just to make a design smaller – it actively improves performance. Here the throughput for reading and writing to microSD is tested on Raspberry Pi 3 Model B and Raspberry Pi 4 Model B and compared to Raspberry Pi Compute Module 4's eMMC – showing a generational boost of between 3.5× and 4.4×.

Storage Throughput (Read)

Storage Throughput (Write)

Megabytes Per Second *(Higher is better)*
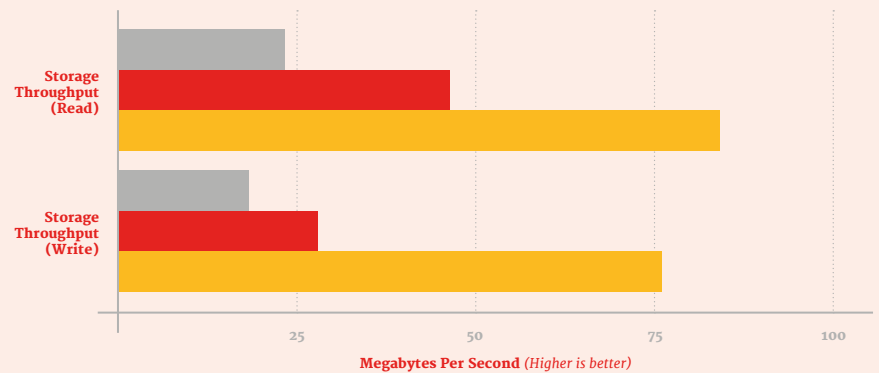
Memory Bandwidth

The move from LPDDR2 to LPDDR4 memory between Raspberry Pi Compute Module 3+ and Raspberry Pi Compute Module 4 brings with it boosted bandwidth, as well as the choice of capacities over 1GB – ideal for more complex workloads such as on-device machine learning or in-memory databases.

Memory Bandwidth (Read, 1MB Blocks)

Memory Bandwidth (Write, 1MB Blocks)

Megabytes Per Second *(Higher is better)*

Legend:
- CPU Temperature
- CPU Clock
- CPU Clock *(Moving Average)*
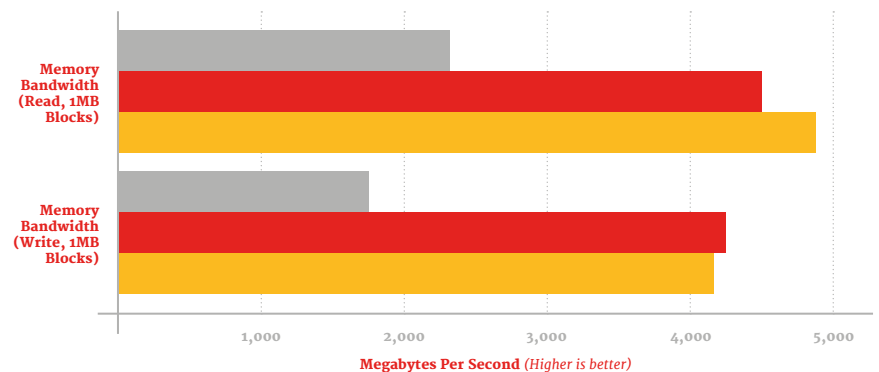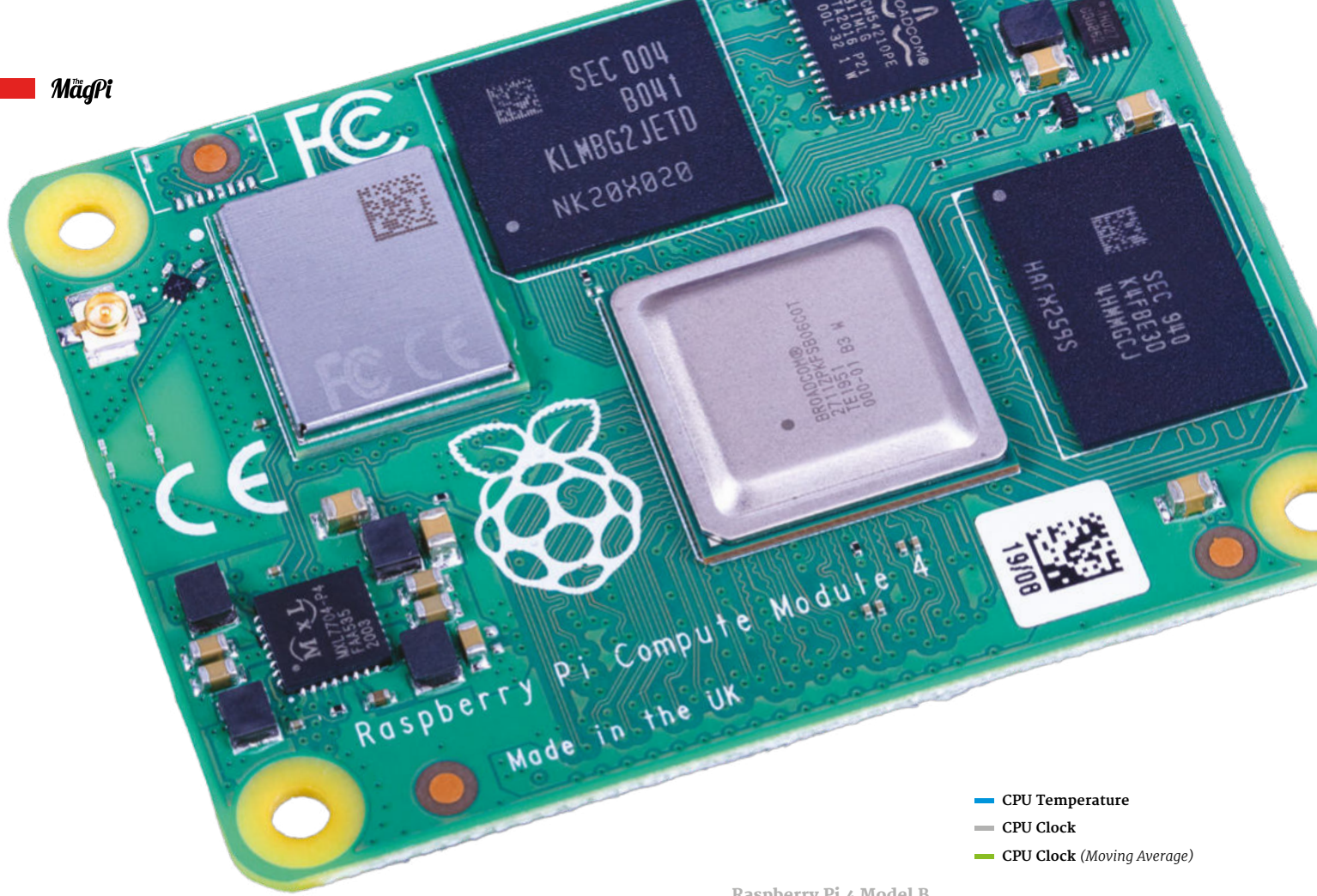
Thermal Throttling

The toughest benchmark of all, this synthetic test puts both the CPU and GPU under heavy sustained load, causing it to rapidly heat up. While both Raspberry Pi 4 Model B+ and Raspberry Pi Compute Module 4 adjust the frequency to protect the CPU and GPU, it's the smaller Raspberry Pi Compute Module 4 which adjusts more rapidly.

Higher CPU clock is better, lower CPU temperature is better

Raspberry Pi 4 Model B

> 𝟕 The toughest benchmark of all, this synthetic test puts both the CPU and GPU under heavy sustained load 𝟕

Raspberry Pi Compute Module 4

Power Draw

Moving away from a single-board computer to a modular format allows hardware designers to pare a system down to only the parts they need, saving footprint, weight, cost, and power. Here, Raspberry Pi Compute Module 4 with the official Breakout Board is compared to Raspberry Pi 3 Model B and Raspberry Pi 4+ for idle and loaded power draw.

Legend:
- Raspberry Pi 3B
- Raspberry Pi 4
- Compute Module 4

Watts *(Lower is better)*
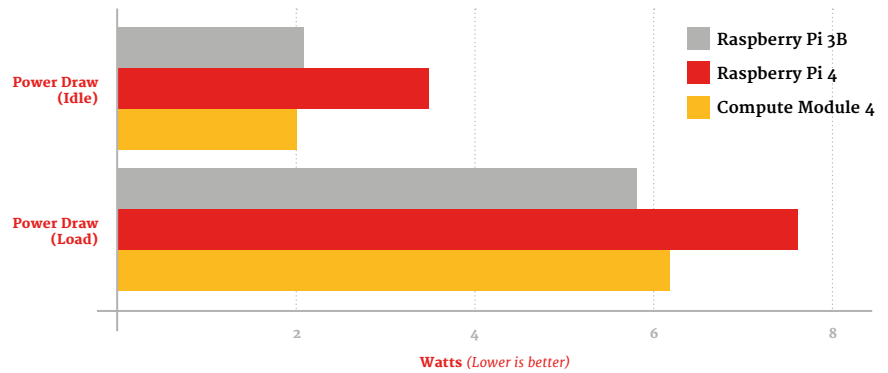
Footprint

A major advantage of Compute Module's form factor is its footprint. Compute Module 4 is considerably smaller than a full-size Raspberry Pi board – perfect for embedding into other devices from monitors and TVs to industrial robots and even self-driving vehicle systems. Here, the two-dimensional footprints of the three boards are compared – but remember, a Compute Module needs a carrier board for the development process.

Square Millimetres *(Smaller is better)*
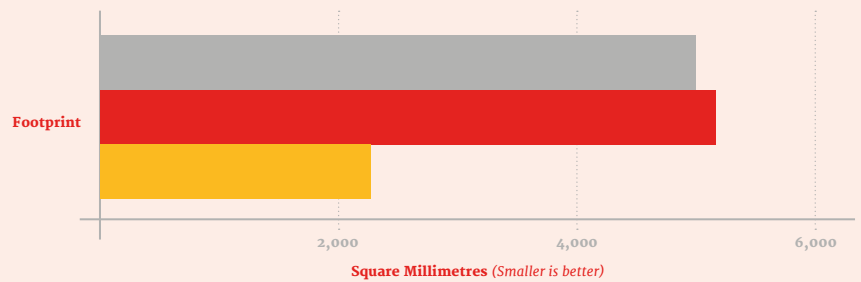
Weight

A smaller board is a lighter board, and Raspberry Pi Compute Module 4's design helps to keep the weight down over its rivals. As with the footprint benchmark, though, the weight measured here is module-only: the functional weight will depend on how many features your carrier board chooses to break out.

Grammes *(Smaller is better)*
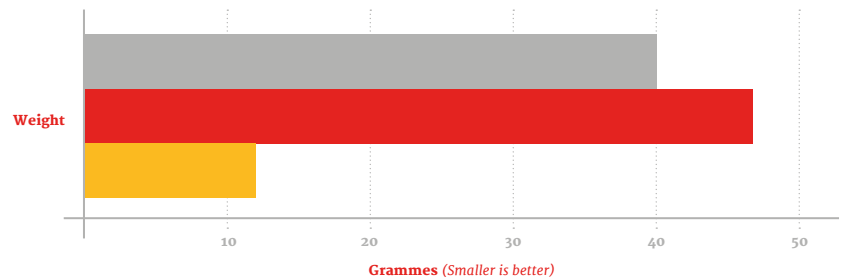
Compute Module 4 Storage Benchmark

Your choice of storage has a direct impact on the throughput you can expect with any Raspberry Pi model. Maximum performance comes from using a Non-Volatile Memory Express (NVMe) SSD connected to Raspberry Pi Compute Module 4's PCI Express (PCIe) lane, offering over 417MB/s read throughput.

Legend:
- Read
- Write

Megabytes Per Second *(Higher is better)*
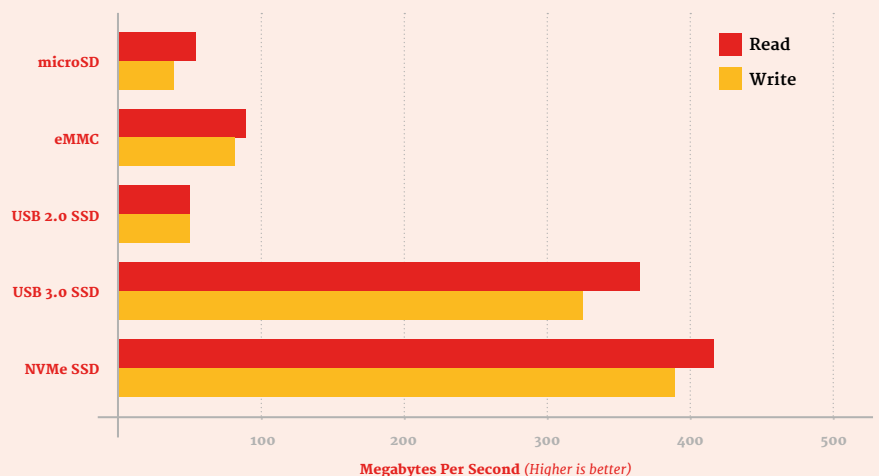
Carrier boards

Raspberry Pi Compute Module 4 has few connectors of its own: the w antenna connector and the two high-density connectors on the underside.

Instead, Compute Module relies on a carrier board – and the features available will depend on what features the carrier board breaks out.

Raspberry Pi Compute Module 4 Input/Output (IO) Board, an open-source design, is designed to help developers get started: it brings out features including two full-size HDMI ports, Gigabit Ethernet, two USB ports, a 40-pin general-purpose input/output (GPIO) header, a Power over Ethernet (PoE) header, two DSI ports, two CSI ports for cameras, a PCI Express slot, and more.

Other carrier boards compatible with Raspberry Pi Compute Module 4 may be specialised for particular tasks, offering specific features or adding extra hardware of their own. Designers can tailor the carrier board to a particular task, but all carrier boards will be mechanically compatible with all Raspberry Pi Compute Module 4 models.
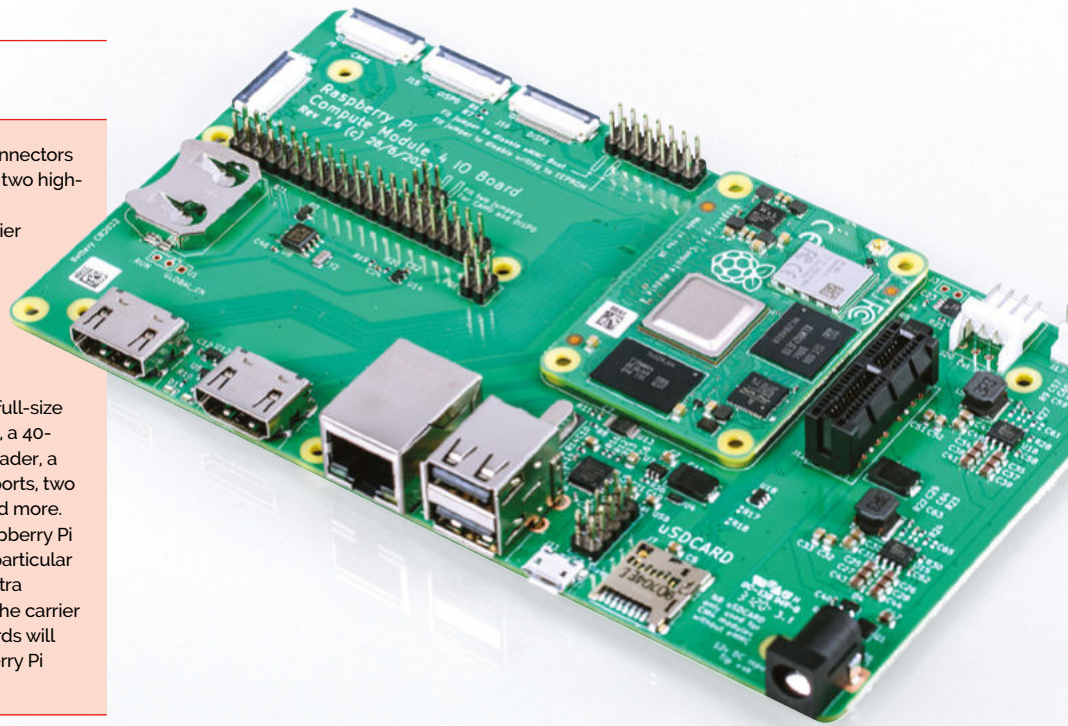
Places to buy

UK & Ireland

CPC/Farnell
cpc.farnell.com

RS
rs-online.com

Pimoroni
pimoroni.com

Asia

element14
element14.com

Cytron
cytron.io

RS
rs-online.com

Hangzhou Junroc
junroc.com

Silverline
silverlineelectronics.in

Beijing iVision
ivision-tech.world.
taobao.com

North America

Allied Electronics
alliedelec.com

Newark electronics
newark.com

PiShop.us
pishop.us

Europe

Farnell
farnell.com

Reichelt
reichelt.com

RS
rs-online.com

Nettop
nettop.gr

Pi3G
pi3g.com

Totonic
pi-shop.ch

Botland
botland.com.pl

For more approved distributors, please visit **raspberrypi.org/products**
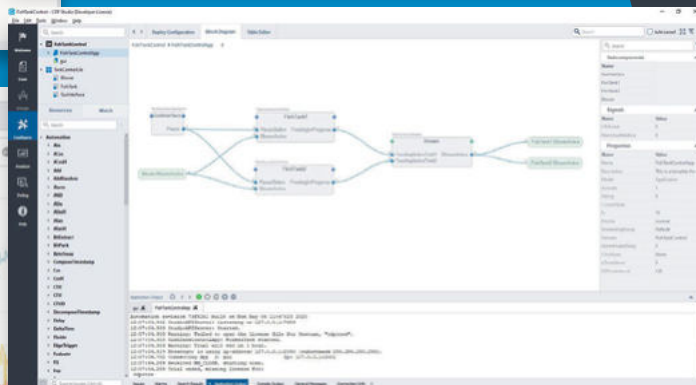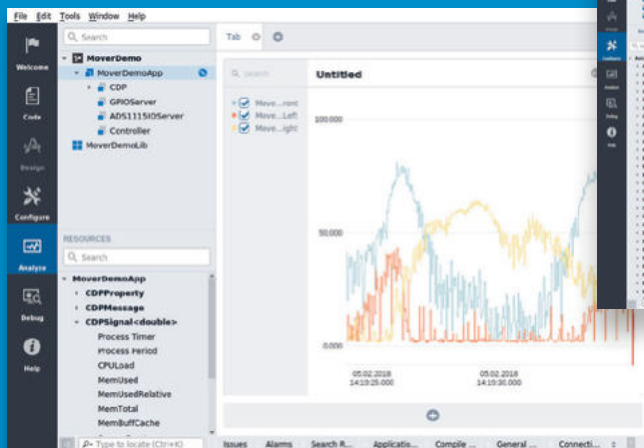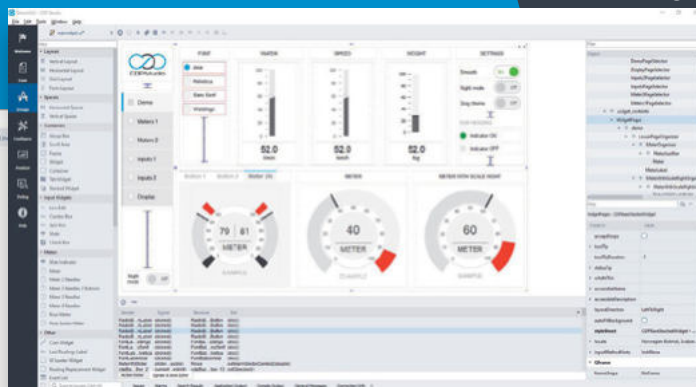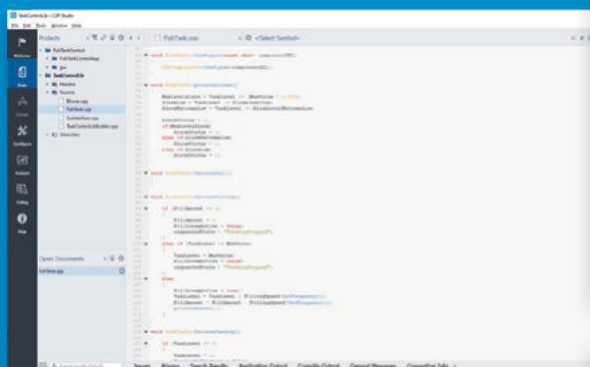
Petoi Bittle
robot dog has bite

Palm-sized Raspberry Pi robot pet prances and performs tricks, reports **Rosie Hattersley**

▲ Petoi Bittle can be assembled in around an hour and has a proper walking motion

Petoi Bittle, a Raspberry Pi-based robot dog that fits in the palm of an adult's hand has caught the imagination of tech enthusiasts.

The teachable robot pet promotes STEM learning and reached its $50K Kickstarter fundraising goal within a day (**magpi.cc/bittleks**). It went on to attract nearly ten times that amount in the subsequent month-long campaign period.

The tiny robot dog is its maker Petoi's second such endeavour: earlier this year it started shipping the successfully crowdfunded Nybble, an open-source robot cat (**magpi.cc/nybble**).

❝ Bittle can go for a walk, avoid obstacles, and right himself if he falls down steps **❞**

Robot pets have been around for more than a decade, but the extensible nature of the Petoi pets makes them ideal for learning how to control robots yourself. Petoi aims to bring down the cost of consumer robots. At around $225 for the Bittle kit, it's aimed at adult tech enthusiasts. Unlike robot toys marketed at children, Bittle is a quadruped with controllable legs. This makes it closer to a £1000+ Sony Aibo robot dog, although the design nods to Boston Robotic's industrial Spot robot.

Bittle has an Arduino controller board for the legs, while Raspberry Pi adds AI elements to the build such as image recognition and tracking (**magpi.cc/bittletracking**). Bittle backers receive components of the robot dog and can share their pet's exploits with others on a dedicated forum: **petoi.com/forum**.

New dog; old tricks

As any Lego, Meccano, or train set designer will tell you, the enjoyment is in the construction at least as much as the finished article.
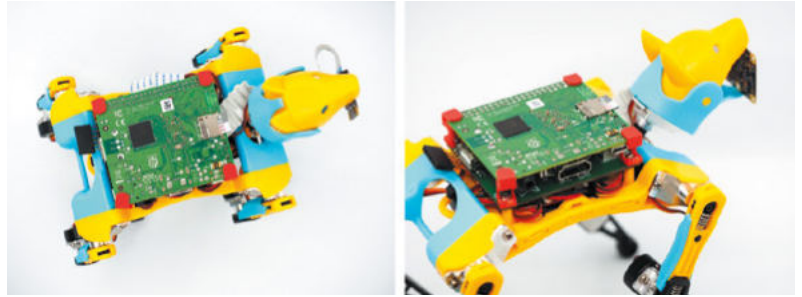
The pet robot will be modular and Petoi claims it takes around an hour to assemble. Its maker explains that the pet dog is assembled from a 'puzzle-like frame' with demo codes downloadable from a GitHub page. Bittle can go for a walk, avoid obstacles, and right himself if he falls down steps (**magpi.cc/bittleyoutube**).

While teaching Petoi tricks will bring its own rewards, there will also be a competitive element. Owners can enter their robot pet into a virtual dog show and demo the skills they've both learned. ▥

▲ Arduino and Raspberry Pi provide the robot dog's controls and artificial intelligence

▲ The pictures taken by Daniel will be compiled into 3D

The Howff
3D scanning rig

How do you create a 3D model of a historic graveyard? With eight Raspberry Pi computers, as **Rob Zwetsloot** discovers

MAKER

Daniel Muirhead

A 3D artist with an interest in historical architecture, developing methods for reproducing Scotland's built environments in full-scale 3D.

danielmuirhead3d.art

"In the city centre of Dundee is a historical burial ground, The Howff," says Daniel Muirhead. We should probably clarify that he's a 3D artist. "This old graveyard is densely packed with around 1500 gravestones and other funerary monuments, which happens to make it an excellent technical challenge for photogrammetry photo capture."

This architecture, stone paths, and vibrant flora is why Daniel ended up creating a 3D-scanning rig out of eight Raspberry Pi computers. And the results are quite stunning.

"The goal of this project was to capture photos for use in generating a 3D model of the ground," he continues. "That model will be used as a base for attaching individual gravestone models and eventually building up a full composite model of this complex subject. The ground model will also be purposed for rendering an ultra-high-resolution map of the graveyard. The historical graveyard has

a very active community group that are engaged in its study and digitisation, the Dundee Howff Conservation Group, so I will be sharing my digital outputs with them."

Google graveyard

To move the rig throughout the graveyard, Daniel used himself as the major moving part. With the eight Raspberry Pi cameras taking a photo every two seconds, he was able to capture over 180,000 photos over 13 hours of capture sessions.

"The rig was held above my head and the cameras were angled in such a way as to occlude me from view, so I was not captured in the photographs which instead were focused on the ground," he explains. "Of the eight cameras, four were the regular model with 53.5° horizontal field of view (FoV), and the other four were a wide-angle model with 120° FoV. These were arranged on the rig pointing outwards in eight different directions,

0cm —

10cm —

20cm —

Eight Raspberry Pi computers are mounted to the ball, with cameras pointing towards the ground

Each Raspberry Pi is simply powered by a mobile power bank

Daniel held the rig above his head, which allowed him to hide from the cameras

Quick **FACTS**

> The camera rig takes 240 photos a minute, or 14,400 an hour

> Daniel created an audio track with beeps to tell him when to stop and when to move

> Daniel had never used a Raspberry Pi for a project like this before

> Daniel used a mixture of standard Camera Module V2s and special versions with wide-angle lenses

> You can see an example of Daniel's work here, a 3D model of Dundee city centre: **magpi.cc/ 3ddundee**

▲ The software builds up the 3D model of the graveyard

◄ The full device is quite long, enabling Daniel to stay unseen by its photos

alternating regular and wide-angle, all angled at a similar pitch down towards the ground. During capture, the rig was rotated by +45° for every second position, so that the wide-angles were facing where the regulars had been facing on the previous capture, and vice versa."

> ❝ This old graveyard is densely packed with around 1500 gravestones and other funerary monuments ❞

Daniel worked according to a very specific grid pattern, staying in one spot for five seconds at a time, with the hopes that at the end he'd have every patch of ground photographed from 16 different positions and angles.

▼ There are thousands of pictures, like this one, being used to create the model

▲ The stick and cameras are quite durable
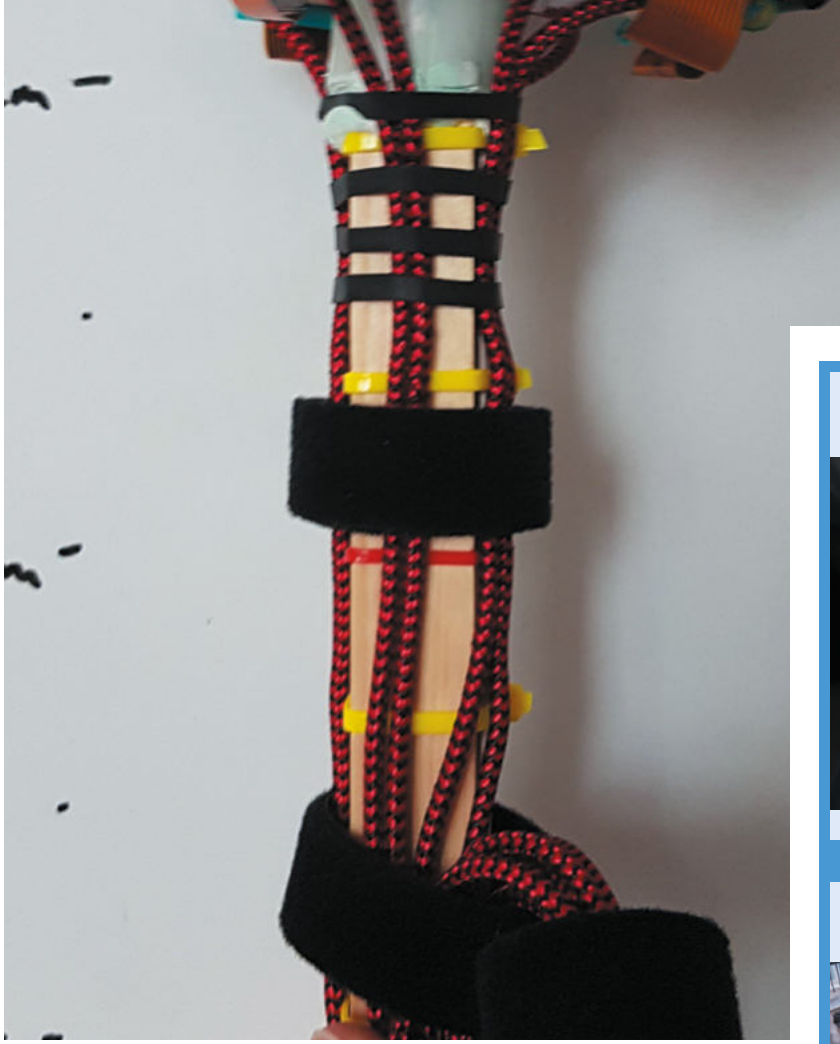
"With a lot of photo data to scan through for something fairly complex, we wondered how well the system had worked. Daniel tells us the only problems he had were with some bug fixing on his code: "The images were separated into batches of around 10,000 (1250 photos from each of the eight cameras), plugged into the photogrammetry software, and the software had no problem in reconstructing the ground as a 3D model."

Accessible 3D surveying

He's now working towards making it accessible and low-cost to others that might want it. "Low-cost in the triple sense of financial, labour, and time," he clarifies. "I have logged around 8000 hours in a variety of photogrammetry softwares, in the process capturing over 300,000 photos with a regular camera for use in such files, so I have some experience in this area."

"With the current state of technology, it should be possible with around £1000 in equipment to perform a terrestrial photo-survey of a town centre in under an hour, then with a combined total of maybe three hours' manual processing and 20 hours' automated computer processing, generate a high-quality 3D model, the total production time being under 24 hours. It should be entirely plausible for a local community group to use such a method to perform weekly (or at least monthly) 3D snapshots of their town centre." **M**

3D scanning
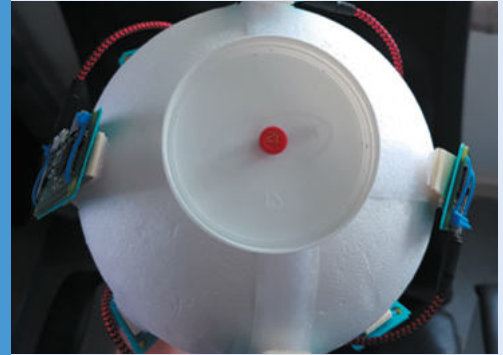
01 Each camera starts working the moment the project's Raspberry Pi computers are fully powered on – roughly 30 seconds from being plugged into the battery pack power sources.

02 Standing still in each location for five seconds allows for several photos to be taken with as little motion blur as possible, with exactly one second to move until the next batch are shot.

03 Unplugging Raspberry Pi computers is the only way to switch them off, and then it's off to another computer to compile all the images.

Raspberry Pi Prayer
Reminder Clock

Designed to be installed on the wall of a mosque, Muslim school, or home, this project makes it easy to display accurate prayer times, as **David Crookes** discovers

MAKER

Ibrahim

The founder of Mawaqit is a lead PHP developer and software architect with more than ten years' experience in various IT projects, and the project is worked on by a team of volunteers.

mawaqit.net

MAKER

Yassine

Yassine is a J2EE software architect with more than ten years' experience in various IT projects.

mawaqit.net

Setting the exact prayer times for a mosque has not always been an easy task. It has generally entailed manually adjusting old clocks or electronic boards, something which has frustrated many worshippers over the years.

"Old clocks are not precise – you set the city, but the prayer times are not correct and you have to regularly adjust them," says Yassine. He's part of a volunteer project team that has worked on a solution. Set up by founder Ibrahim, the group has found a Raspberry Pi computer to be the right tech for the task.

The result has been an advanced, information-rich prayer clock for mosques – one which can broadcast the weather, make announcements, and even issue reminders to silence a mobile phone. Called Mawaqit, it also displays religious guidance every five minutes. "Video of Al-Jumu'ah [Friday prayer] can be shown as well," says Yassine.

It's the essential information that has made Mawaqit particularly useful. "It displays the current date and time, as well as the current Hijri date [the Islamic calendar] which is automatically

▲ Messages and announcements can be sent to Raspberry Pi from a computer via a web application
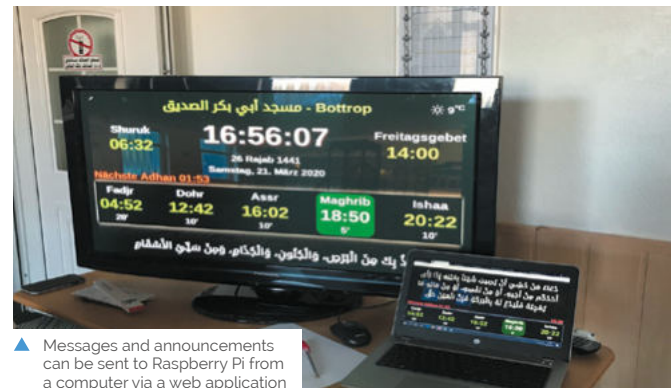
calculated by the software and adjustable by the user," Yassine explains. "There's also the name of the mosque, with prayer times of the current day displayed alongside the time left to the next prayer."

Simplicity is key

Right from the start, the aim was to keep the project as simple as possible. "All the technical needs are provided by a Raspberry Pi computer, a display, and a HDMI cable," says Yassine.

But such simplicity is part of the appeal. "Raspberry Pi is affordable and it's small, which makes it easy to put behind a TV," Yassine continues. Indeed, the team ensures that all of the hard work is taken care of, with help and advice only a social media message or email away, leaving users of this open-source project to benefit from the results.

"We regularly deploy new features and fix bugs and we're in close touch with users to offer technical support," Yassine says. "We have a YouTube channel that explains how it works, an

▶ This mosque connects Raspberry Pi to a projector to beam the information on to a wall

Raspberry Pi simply plugs into a television using a HDMI cable, and the software can be remotely controlled from a smartphone, computer, or tablet

Once Etcher is installed and the mawaqit.zx system image is flashed on to Raspberry Pi's microSD card, users can begin to set up the app

Mawaqit can be used online or offline: for offline use, a real-time clock needs to be connected to Raspberry Pi

Quick **FACTS**

> The project provides exact prayer times

> It outputs information on a television

> Control is via an always-available web app

> It's used in 4693 mosques (and counting)

> About 2930 of them are in France

API which lets users create their own extensions, and we even have a mobile app version on iOS and Android."

Easy installation

Getting going is as easy as installing the preconfigured system image and flashing it onto Raspberry Pi's microSD card. The latest updates install automatically and the software can be remotely controlled from a smartphone, tablet, or computer.

Although Mawaqit is a web application that can be preconfigured by mosque managers using an online tool to manage schedules, news, and other features, the project supports a real-time clock for offline installations. "We also configured Mawaqit to auto-start at boot using the Chromium browser," adds Yassine.

With all this in mind, it's little wonder Mawaqit is being used in more than 4600 mosques in 51 countries. "The feedback has been very good," says Yassine. "Raspberry Pi is now seen as an absolute necessity not only in mosques but homes as well, and everyone who starts to use it never takes it down."

> **Raspberry Pi is affordable and it's small which makes it easy to put behind a TV**

▼ Lots of information can be displayed on the prayer clock, all determined by the user

Remote Humidity
Detector

Crawl spaces are not for the claustrophobic – or anyone with a fear of creepy-crawlies.
David Crookes looks at how Jamie Bailey monitors his from afar

MAKER

Jamie Bailey

Jamie Bailey is the founder of the data streaming and visualisation platform Initial State, as well as a self-confessed nerd.

**magpi.cc/
humiditymonitor**

After building a new house, Jamie Bailey went where no person ever really wants to go – into the dark, cramped crawl space beneath the property to check for humidity. "It wasn't fun and I only got a single humidity reading," he confesses. But since this particular crawl space uses external vents and Tennessee, where Jamie lives, is very humid in the summer, it was certainly a necessary trip.

Excess humidity is a problem, particularly in the dark. It can cause mould to grow and infiltrate a home's air, and that's a potential health hazard for those living there. "I became worried about the humidity causing long-term issues, including wood rot in the floor joists which is super-expensive to repair," Jamie says.

"So, I went in with a handheld humidity meter and realised I needed to log the levels over many weeks and months. Going down there every day wasn't going to happen. Thus, the idea of using a Raspberry Pi computer to do the work for me was born."

Humidity hardware

Jamie's checklist of hardware was relatively small. As well as a Raspberry Pi 3, 4, Zero W, or Zero WH model with pre-soldered headers, he reckoned on needing a humidity sensor and a power outlet. "There was no power down there and using batteries was a non-starter for me, but getting electricity under the house was easy because of the existing wiring," he says.

He also sought an accurate humidity sensor. "This was harder than it should have been because I thought the popular DHT22 temperature/humidity sensor (**magpi.cc/dht22**) would be perfect, but it turned out to be a bust after testing four of them and getting completely different readings from each one," he tells us. Jamie tried an

▲ Crawl spaces promote the circulation of air and allow access to essential utilities, but they can be a magnet for insects, moisture, and mould

inexpensive BME280 temperature/humidity sensor (**magpi.cc/bme280**) and got it working with Python in just five minutes. "I knew I had a winner."

The sensor easily connected to the pins of Raspberry Pi, leaving the rest of the work down to the software. Jamie installed Raspberry Pi OS, hooked up to his home's wireless LAN, and got to work on the Python script. He used Initial State (**initialstate.com**) for the data streaming and visualisations needed to make sense of the information.

Gathering data

"A huge part of this project that I didn't realise I needed was outside temperature and humidity," he says. "Just reading relative humidity in the crawl space wasn't enough because of the vents – I needed to know what was going on outside too. The crawl space stays much cooler than the outside during summer, and cooler air holds less moisture than warmer air.

"When that hot humid air gets sucked into the crawl space, the relative humidity goes up about 2.2 percent per each degree in Fahrenheit.

By hanging the project from a floor joist, it's kept away from any water that may be pooling on the ground

Once Raspberry Pi was set up using a wireless keyboard and mouse, it could be encased and put into place in Jamie's crawl space

Each BME280 temperature/humidity sensor he tested recorded the same level – not bad for a device costing $4.50

Quick **FACTS**

> This project is ideal for monitoring humidity anywhere

> Fit a power outlet or use an extension cord

> It can make use of a headless Raspberry Pi Zero

> Raspberry Pi OS allows for remote management through SSH

> Early detection of elevated humidity avoids costly repairs

" A huge part of this project that I didn't realise I needed was outside temperature and humidity "

I needed to log what was happening outside along with what was happening under the house, so I used Weatherstack (**weatherstack.com**) to get the outside weather information into my dashboard, although I could have also used a second Raspberry Pi outside to do the same thing."

Jamie can now monitor the average outside temperature and humidity and see the average within his crawl space. "The project is a good framework to monitor just about anything with a sensor," he says. "I plan to use it for many more projects that are currently swirling around in my head." M

▲ Data gathered by the sensor are sent via wireless LAN to a dashboard in Initial State. Alarms can be sent via email or text to a mobile device too

Mars Clock

A sci-fi writer wanted to add some realism to his fiction. The result:
a Raspberry Pi-based Martian timepiece. **Rosie Hattersley** clocks in

Philip Ide

A professional
programmer since
the 1980s, Philip has
been obsessed with
Mars "since he first
turned a telescope
to it."

philip-p-ide.uk

MAKER

Ever since he first saw Mars through the
eyepiece of a telescope, Philip Ide has been
obsessed with the Red Planet. He's written
several books based there and, many moons ago,
set up a webpage showing the weather on Mars.

This summer, Phil adapted his weather monitor
and created a Raspberry Pi-powered Mars Clock.

Mission: Mars

After writing several clocks for his Mars Weather
page (**magpi.cc/marsweather**), Phil wanted to
make a physical clock: "something that could sit
on my desk or such like, and tell the time
on Mars."

It was to tell the time at any location on Mars,
with presets for interesting locations "plus
the sites of all the missions that made it to the
surface – whether they pancaked or not." Another
prerequisite was that the clock had to check for

new mission file updates and IERS bulletins to
see if a new leap second had been factored into
Universal Coordinated Time.

"Martian seconds are longer," explains Phil, "so
everything was pointing at software rather than a
mechanical device. Raspberry Pi was a shoo-in for
the job." However, he'd never used one.

"I'd written some software for calculating orbits
and one of the target platforms was Raspberry Pi.
I'd never actually seen it run on a Raspberry Pi but
I knew it worked, so the door was already open."
He was able to check his data against a benchmark
NASA provided.

Knowing that the clocks on his Mars Weather page
were accurate meant that Phil could focus on getting
to grips with his new single-board computer.

He chose a 2GB Raspberry Pi 4 and official
7-inch touchscreen with a SmartiPi Touch 2 case
(**magpi.cc/smartipi2**). "Angles are everything,"
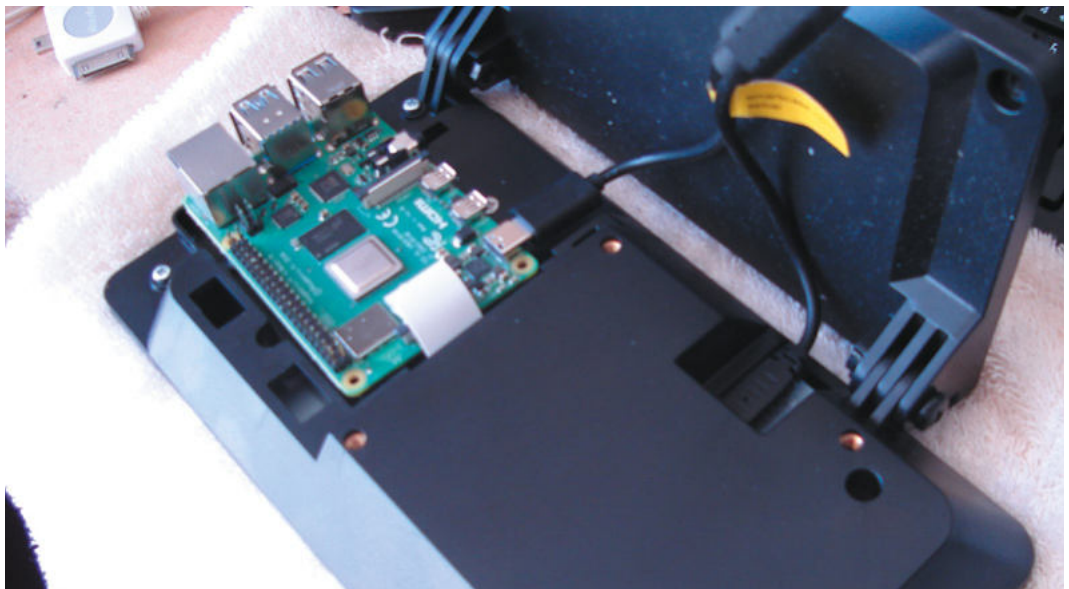
▶ The projects runs on
a 2GB Raspberry Pi 4
with official 7-inch
touchsceen
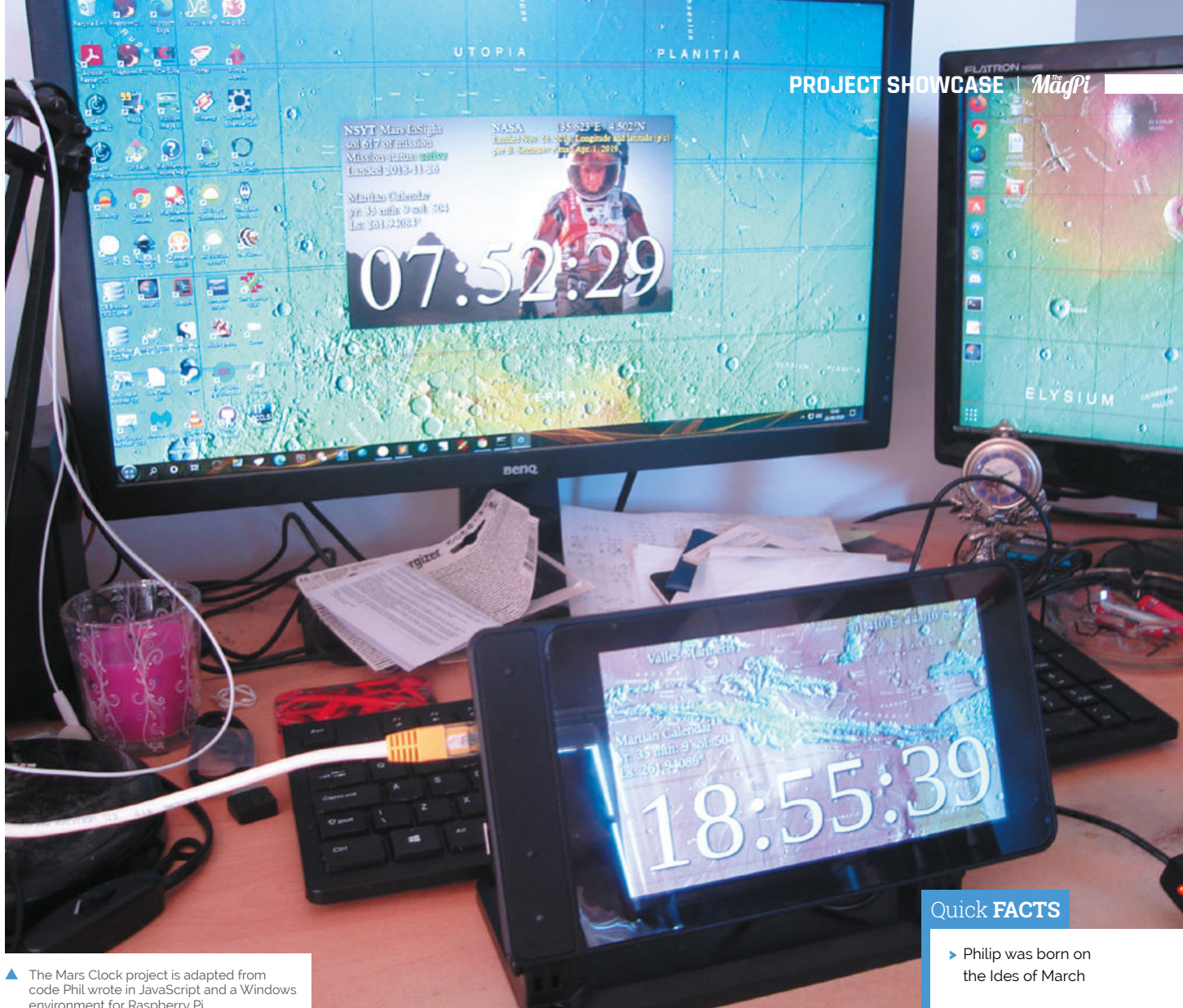
▲ The Mars Clock project is adapted from code Phil wrote in JavaScript and a Windows environment for Raspberry Pi

Credit: NASA/JPL-Caltech/Cornell/CAB +

Latest Weather at Elysium Planitia

InSight is taking daily weather measurements (temperature, wind, pressure) on the surface of Mars at Elysium Planitia, a flat, smooth plain near Mars' equator.

Sol 656
September 30

High: -3° F
Low: -143° F / C

Sol 654 Sep. 28	Sol 655 Sep. 29	Sol 656 Sep. 30
High: 4° F Low: -140° F	High: 0° F Low: -139° F	High: -3° F Low: -143° F

Quick **FACTS**

> Philip was born on the Ides of March

> He writes science fiction as well as code

> His Orbital Calculator helps other science fiction writers…

> …get their space travel calculations right

> This is his first Raspberry Pi project
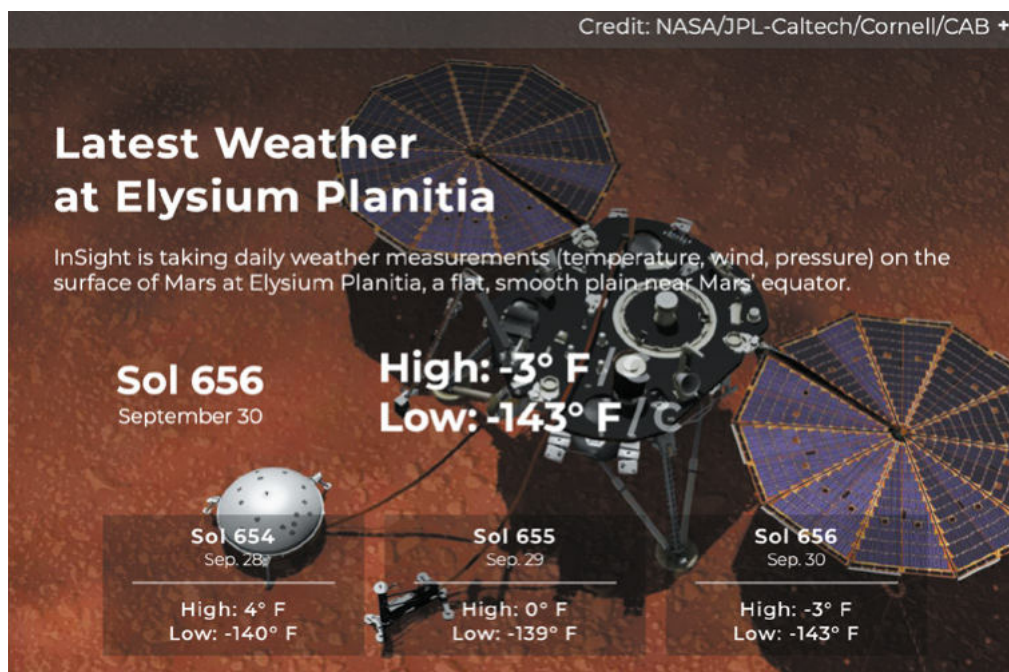
◄ Phil's Mars Weather page shows seasonal trends since March 2019. If the clock is within 300km of the InSight lander, it will pull down the latest weather report from NASA

Raspberry Pi 4 and a 7-inch touchscreen display were ideal for creating a physical clock based on code Phil had written for his Mars Weather page

You can jump to the locations of NASA's Mars missions to check the time and data there. Mars Clock is set to pull down the latest weather information there too

The SmartiPi Touch 2 case houses Raspberry Pi 4 and a fan to cool its CPU

The Mars Clock's various skins show details of missions to Mars, as well as the location's time and date

he reasons. He also added a fan to lower the CPU temperature and extend the hardware's life. Along with a power lead, the whole setup cost £130 from The Pi Hut.

Since his Mars Clock generates a lot of data, he made it skinnable so the user can choose which pieces of information to view at any one time. It can display two types of map – Viking or MOLA – depending on the co-ordinates for the clock. NASA provides a web map-tile service with many different data sets for Mars, so it should be possible to make the background an interactive map, allowing you to zoom in/out and scroll around. Getting these to work proved rather a headache as he hit incompatibilities with the libraries.

Learn through experience

Phil wrote most of the software himself, with the exception of libraries for the keyboard and FTP which he pulled from GitHub. Details of the code are at **magpi.cc/marsclockgithub**.

There's a range of skins to choose from for the clock display
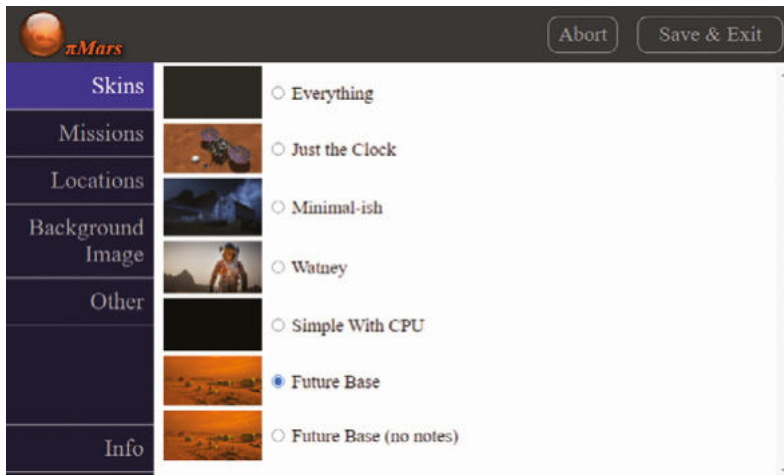
He used JavaScript running on the Node.js/Electron framework. "This made for rapid development and is cross-platform, so I could write and test it on Windows and then move it to the Raspberry Pi," he says. With the basic code written, Phil set about paring it back, reducing the number and duration of CPU time-slices the clock needed when running. "I like optimised software," he explains.

His decades as a computer programmer meant other aspects were straightforward. The hardware is more than capable, he says of his first ever experience of Raspberry Pi, and the SmartiPi case makers had done a brilliant job. Everything fitted together and, in just a few minutes, his Raspberry Pi was working.

> ❝ Martian seconds are longer, so everything was pointing at software rather than a mechanical device job ❞

Since completing his Mars Clock, Phil has added a Pi-hole and a NAS to his Raspberry Pi setup and says his confidence using them is such that he's now contemplating challenging himself to build an orrery (a mechanical model of the solar system).

"I have decades of programming experience, but I was still learning new things as the project progressed," he says. "The nerd factor of any given object increases exponentially if you make it yourself." 🅼

Tell Martian time

01 Instructions for setting up your own Mars Clock are given at **magpi.cc/marsclockinfo**. You'll need a Raspberry Pi 4 if you use a SmartiPi Touch 2 case.

02 Fit Raspberry Pi into the case. Adjust the touchscreen's display brightness to 50 and install Node.js v14 – a newer version than that in Raspberry Pi OS. Create a folder called **Autostart** in **./config** and set marsclock.desktop to autorun.

03 Clone the repository:
```
cd ~/
git clone github.com/phil-ide/marsclock.git
```
Install the marsclock application and check it runs. This needs to be in a Desktop environment, not SSH. Reboot your Raspberry Pi.

Smart Garden BBQ

What do you do when your BBQ no longer BBQs? Well, you could repurpose it as a smart garden and reap the flavourful rustic rewards. **Nicola King** gets green-fingered…

MAKER

Etienne Deneault

Las Vegas-based Etienne is an acrobatic coach at Cirque du Soleil, and a developer in training. He enjoys technical challenges and complex problems. He's curious by nature and enjoys the process of building.

medium.com/ @edeneault

When Etienne Deneault was searching for a new Raspberry Pi project and, at the same time, wondering what to do with his broken Weber BBQ, he hit on a great idea. Having seen how other makers had converted old BBQs into planter box gardens, the seeds of an idea were planted. "The convergence of the two ideas was what motivated me to build it," he explains. "I also liked the 'Americana' influence captured by the use of the Weber grill. Weber is an icon of the American backyard BBQ culture; I like that it can continue to serve up food for us humans to enjoy."

Horticultural haven

Armed with his elderly BBQ and a Raspberry Pi–based Smart Garden System Kit (SGS v1) from SwitchDoc Labs, Etienne set to work to inject new life into the old grill. He needed to make modifications to both the Smart Garden System Kit and the BBQ – for example, the Smart Garden Kit was designed for indoor use, so Etienne needed to 'weatherise' it, and the BBQ had to be transformed into a planter box with an adequate drainage system, which required some carpentry and plumbing skills to be called into action. This didn't hold Etienne back, however: "I found a tutorial video on building planter boxes and applied some of the knowledge that I learned watching it. I have built significantly more complex carpentry projects than this one in the past."

Once his planter was ready to propagate, the technical side came into play. "The Smart Garden works essentially in an 'event-based' model," he says. "It uses a module in Python called APScheduler to create recurring events.
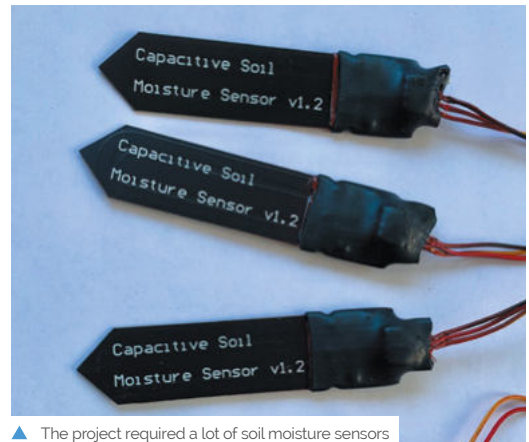
▲ The project required a lot of soil moisture sensors

▼ Testing the watering system before the final build

For example, it will 'check' the soil moisture sensor level every 15 minutes. If the return of this 'check' is below a predetermined moisture threshold, then an 'alarm' is created to water the plant." The tank capacity is also monitored by an ultrasonic sensor which again triggers an alarm when the water level gets too low. However, the other sensors – including air quality, sunlight, and temperature – are for information purposes only, so no alarms are required.

Etienne did some tweaking to the Python code to fit his specific needs in the extreme Las Vegas environment – for example, he changed the soil moisture check to every five minutes instead of 15, so that plants wouldn't have to wait too long to be watered, and he changed the length of watering time so that they got enough water. He also tells us that he used a longer 'dumb' moisture sensor to measure deeper into the soil than the moisture sensors of the Smart Garden can reach. "The soil moisture at seven inches deep was not high enough," he explains.

Feeling hot, hot, hot

So, what's Etienne growing and how are the plants faring? Having originally planted tomatoes and peppers a little too late, he soon found that the Las Vegas summer desert temperatures proved too

A selection of plants including tomatoes and peppers

Etienne surrounded the metal frame of the BBQ with wooden panels

An ultrasonic sensor measures the tank's water level

> **" A mixed vegetable grilled antipasto is delicious eating for a BBQ; this Weber won't be cooking it, but it might provide some of the ingredients "**

much for his young vegetables and they succumbed to the extreme heat (up to 46°C!) That said, he's now feeling more confident: "Now that the heat of the summer is passed, I have planted again for the fall season. I am growing mini yellow squash, mini cucumbers, and a poblano pepper plant. I am not late planting this time around, so I am optimistic that the result will be good."

Feedback from family and friends has been very positive, and it has educational benefits too. "They also appreciate that I do these projects, not only because I enjoy them, but to expose my son to STEAM educational opportunities," reveals Etienne. "I can clearly see the evolution of his questions over time, reflecting his increasing understanding." He adds, "A mixed vegetable grilled antipasto is delicious eating for a BBQ; this Weber won't be cooking it, but it might provide some of the ingredients!"

It's an excellent and pleasurable project where you should (extreme temperatures permitting!) have something to show for your labours at the end – why not try it yourselves? 🅼

▲ Coming along nicely! Etienne's plants are now thriving

Coffee Stirrer Camera

Capturing photos through a 'lens' of thousands of coffee straws, this strange camera produces some amazing images. **Phil King** goes for a close-up

MAKER

Adrian Hanft

Adrian is an author, artist, runner, and UX Designer from Colorado. His experimental approach to photography has led him down unusual paths, from creating pinhole cameras out of Lego to his current project, a camera made of 23,248 coffee stirrers.

adrian3.com

This isn't the first time Adrian Hanft has built an innovative photography device: back in 2004, his Lego pinhole camera went viral. Now he has created an even weirder camera which makes use of 23,248 coffee stirrer straws and a Raspberry Pi High Quality Camera to capture stunning mosaic-like images (**magpi.cc/coffeecam**).

"I've always loved pinhole cameras," he tells us. "As I played with [them], I wondered if I could create a camera with hundreds of holes instead of a single point of light. That 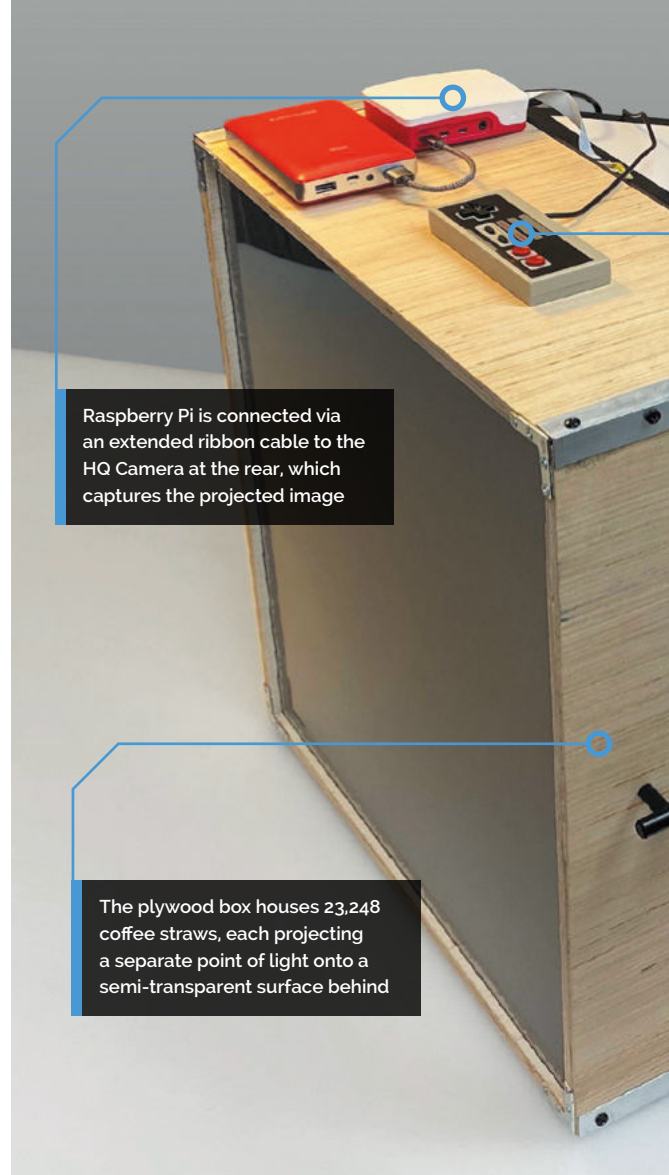little idea virus took hold and eventually I found myself buying out Wal-Mart's entire inventory of straws to test the idea."

He worked on the new camera for about a year, building three prototypes before arriving at the final design. "It's funny how ideas seem like they will work in your head, but then when you build it in real life, things fail in unusual ways. For example, I went to great lengths to find the right surface for the image to be projected on inside the camera. At one point I debated destroying a large TV screen because I thought the matte glass of the TV was what would

work. In the end, the material that worked best was ordinary wax paper. You just never know what will work until you experiment."

Points of light

Adrian explains how the camera works: "Think of a straw as a telescope. Look through it and you see a tiny part of the bigger picture. Stack thousands of straws and all those points of light add up to make a bigger picture. To capture the picture, the light from each straw lands on a semi-transparent surface inside the camera. I take a picture of that projection to get the final image." Exposure times range from one to six seconds. As for focus, the closer things are to the straws, the clearer they appear.

Adrian reveals that when he heard about the new High Quality Camera earlier this year, he knew he had to try it. "I've always wanted to build my own digital camera. Old film cameras are easy to take apart and modify, but digital cameras are black boxes. Until Raspberry Pi's High Quality Camera, it has been virtually impossible to build your own digital camera. Now the sky's the limit."

A Lego mount enables easy attachment of the Raspberry Pi HQ Camera to any of the prototypes.

Raspberry Pi is connected via an extended ribbon cable to the HQ Camera at the rear, which captures the projected image

The plywood box houses 23,248 coffee straws, each projecting a separate point of light onto a semi-transparent surface behind

A Lego mounting system enables the HQ Camera (and an Olympus one) to be switched easily between prototypes

A USB gamepad is used to control the camera's functions and exposure settings

"Lego is a quick and easy way to hold things in place as you are prototyping," notes Adrian.

Public display

The public reaction to the camera has been very positive. "People's first response is skepticism because it sounds like such a strange thing," says Adrian. "But when they see the images it creates, they are won over. They realise it isn't a

> ## Stack thousands of straws and all those points of light add up to make a bigger picture

gimmick, it's a way to create images that are unlike anything else. And now that I am developing a following on Instagram (**@ade3**), it is rewarding to get kudos from people outside my small circle of friends and family."

The camera is ideal for portraits and eventually he wants to have a show where it can be in the gallery alongside the portraits taken with it. "Right now the camera still requires me to be very hands-on, but eventually I think I can to get it to a point where anyone could walk up to the camera and take a selfie. I like the idea of the camera existing on its own without me being there to operate it." M

▶ With each straw delivering a point of light, the resulting mosaic-like image is made up of thousands of small circles
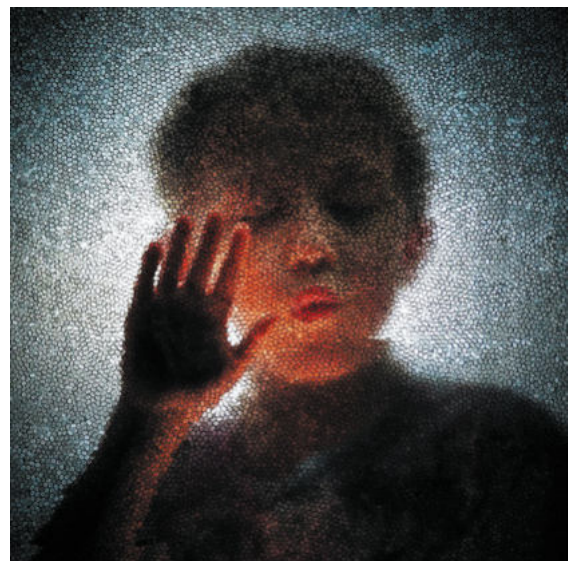
Lunchbox
Arcade Game

▲ Enjoy some lunchtime classic arcade action with this compact gaming system

A gaming fan dumped his sandwiches to become a legend in his own lunch hour. **Rosie Hattersley** finds out how

MAKER

Rich Jones

Engineer Rich lives in north Wales and has built several PCs over the years. He recently began focusing on building arcade machines, hence his YouTube tag 'Arcade Dad'.

magpi.cc/ arcadedad

A fondness for school lunches might be unusual, but we're sure Rich Jones isn't the only person nostalgic for a much-loved lunchbox. The engineer, from north Wales, found himself idly searching for lunchboxes emblazoned with his favourite game, Pac-Man, but baulked at the hefty price tags on eBay and Amazon.

He eventually chose one celebrating a different game, kicking off his Raspberry Pi-based Lunchbox Arcade Game project.

"I used to have a cool metal Pac-Man lunch box for school but trying to get a Pac-Man one is nearly impossible, and ones that do come up go for silly money on eBay," he explains. At more than £60 a tin, he couldn't bring himself to drill holes in an original 1980s version. Instead, Rich decided to modify a Gauntlet one.

Most of the parts, for what became a roughly £250 build, were sourced from Arcade World (**magpi.cc/arcadeworld**).

Lunch bunch

Rich had already built three Windows-based arcade machines having moved on from assembling his own PCs, plus one using Raspberry Pi. For his Lunchbox Arcades, Raspberry Pi was a shoo-in.

"So much power in such a small form factor makes Raspberry Pi a great choice for mini arcade machines," says Rich. "With all my machines the sound quality is important, so I've fitted the largest speakers the lunchbox could realistically support." He strengthened the tin all round using plywood in the base and fitted new rivets into the metal sides.

Next came the lid. He removed the original hinge, realising it wasn't strong enough to support

Inspired by his love of classics, Rich Jones came up with a retro arcade that fits inside a games-themed lunch tin

The Sanwa joystick has a detachable shaft that can be packed away inside the lunchbox arcade

Alert!
Voltage Reducer

This project uses mains electricity with a voltage reducer. Be careful when working with electricity.

**magpi.cc/
electricalsafety**

Quick **FACTS**

> The project took around a week to build

> For v2, Rich will be fitting a Raspberry Pi 4

> ...as well as adding battery power and charge circuits

> He's also on the lookout for a widescreen lunchbox

> ...for a 16:9 RetroPie console. of course

A heatsink needed to be repositioned, which Rich cleverly disguised using a 3D-printed fan grille

the LCD screen. "I was able to gain some height with new hinges. This allows the screen to fold inside the casing, giving a seamless look when shut," Rich says. "The joystick is removable to allow the lid to close. It's a modified Sanwa joystick shaft with a quick release system. The sprung release shaft comes off easily and can be stored in the back of the machine. The original latch holds the lid shut."

It wasn't all straightforward, though: "Airflow was also important, so a 60 mm fan forces air inside over Raspberry Pi and out of two slots cut in the control panel." With hindsight, says Rich, this could have gone on the rear rather than where the handle is. A Gauntlet fan grille he created on a 3D printer now covers it up a bit.

Power play

"The Lunchbox Arcade runs off a 12 V, 6 A power supply. A buck voltage reducer takes this down to 5 V for Raspberry Pi and the screen. "The buck voltage PCB will also look after a rechargeable battery, so I'm trying to source a 12 V battery that will fit in the case and also provide a good few hours playtime," says Rich.

▲ Rich has embarked on a mini arcade collection having previously custom-made a cabinet for another of his self-built Raspberry Pi games machine

◀ A modified Sanwa joystick shaft with a quick-release system for easy removal

▲ The sound quality was really important, so Rich bought a tin he liked but that wasn't so expensive that he had qualms about cutting it up to accommodate large speakers

▲ RetroPie and RetroArch games provide plenty of retro gaming options

" So much power in such a small form factor makes Raspberry Pi a great choice for mini arcade machines "

Although the project has the potential to be self-powered, he didn't want to compromise on the speakers. "The speakers and amp were the whole reason behind the 12 volt power supply. I didn't want some tiny speakers and a 5 V amp." Despite having to reposition the heatsink to accommodate the amp, the audio setup proved worth the extra hassle. "The speakers sound really good as they resonate through the tin and have good bass, which surprised me," says Rich.

He thinks others might enjoy making something similar. Raspberry Pi is perfect for this size of machine. It has plenty of power, great visuals, and no slow-down in the games," he enthuses. If you're embarking on your own arcade project he advises, "Always think about maintenance and how you're going to access all the components in the future. The controls need to be easy to remove, so making up some sort of quick wiring connect that you can just unplug will save a lot of hassle in the future." M

Alert! Use Legal ROMs

It can be illegal to download copyrighted ROM files of games. Stick to legally downloaded ROMs.

magpi.cc/legalroms

Box clever

Source a metal lunch box that's large enough to accommodate Raspberry Pi, speakers, and amp. You'll also need a joystick, ideally with a removable shaft so it can pack away inside your mini arcade box.

01 Connect Raspberry Pi to the LCD screen using an HDMI cable, then plug in an amp to the 3.5 mm audio jack.
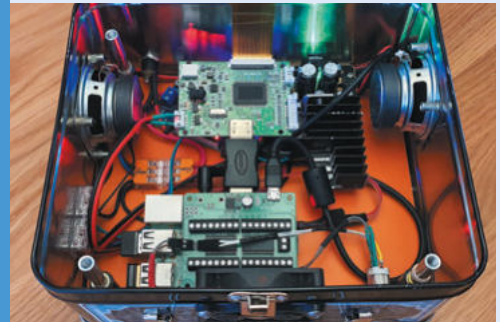
02 Use a USB keyboard converter as a control block to convert arcade buttons to keystrokes. Rich suggests sourcing these from **petrockblock.com.**

03 The control block enables the arcade to safely shut down via the power button on the front. Attach it to Raspberry Pi using the GPIO pins.

Do you know
HOW ROBOTS SEE?
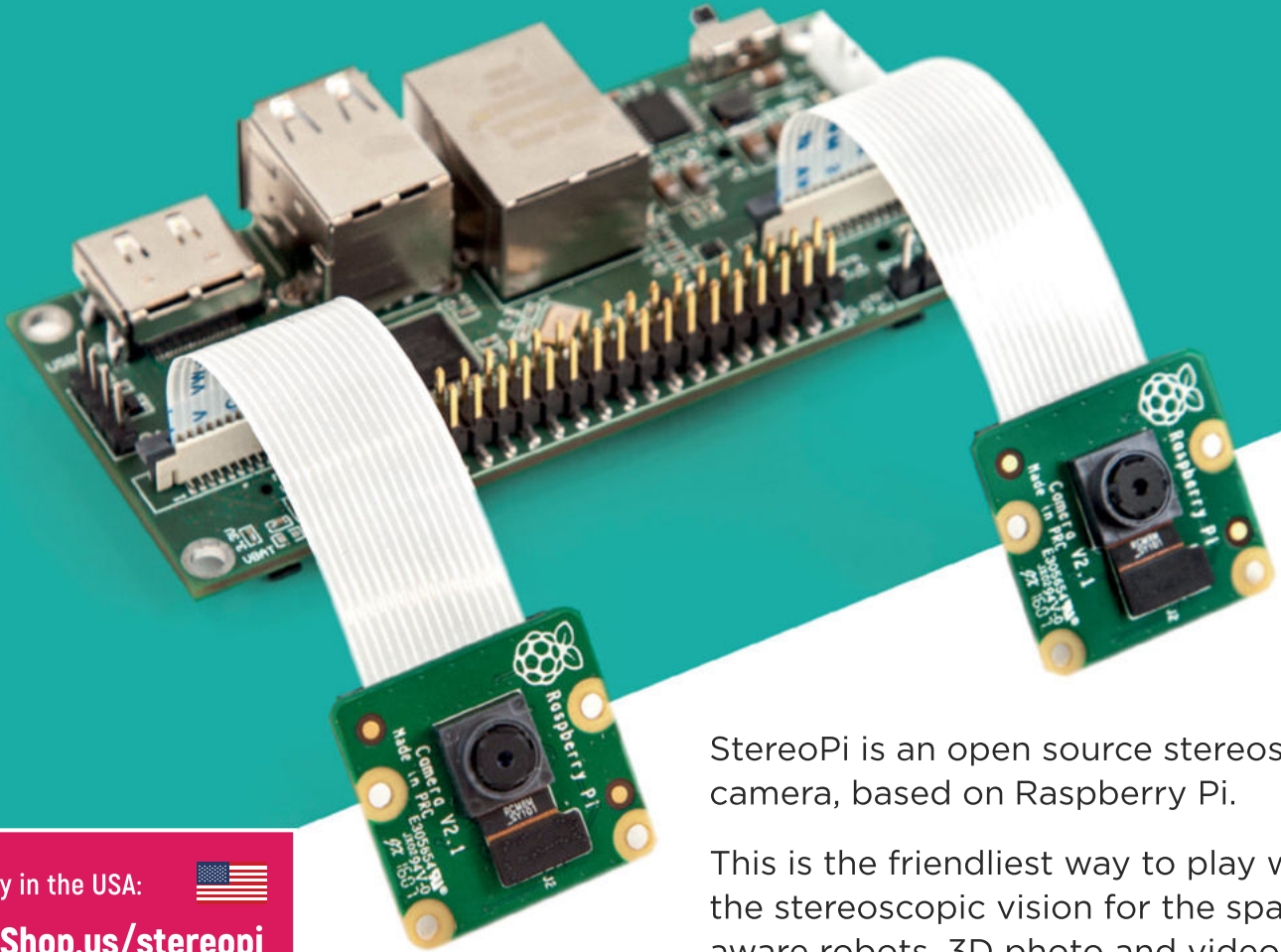
StereoPi is an open source stereoscopic camera, based on Raspberry Pi.

This is the friendliest way to play with the stereoscopic vision for the spatially aware robots, 3D photo and video!

RASPBERRY PI INSIDE

Raspbian
STOCK RASPBIAN SUPPORT

OPEN SOURCE

CROWDFUNDED PROJECT

LinuxGizmos.com
"The StereoPi can capture, save, livestream, and process real-time stereoscopic video and images for robotics, AR/VR, computer vision, drone instrumentation, and panoramic video."

MickMake
"With it you can do things like, stream stereoscopic 3D video to YouTube, build real-time depth maps using OpenCV, create panoramics using Hugin and even a 3rd person view of real life. Cool."

Raspberry Pi Blog
"There are some excellent community efforts too, of which our current favourite is this nifty dual camera board."

Hackster News
"You can hook this up to YouTube, to Oculus Go, you can use it with OpenCV.. I cannot wait to start messing around with these because it's basically a dream come true."

RASPBERRY PI
ULTIMATE
WISHLIST

Raspberry Pi is endlessly customisable and can turn its hand to almost any task you care to dream up. **Rosie Hattersley** suggests ways to make the most of this modular maestro

Hands up if, when you bought your first Raspberry Pi, you got nothing else. Aside from the obvious retort that it needs power, a microSD card for the operating system, an input device, and (usually) a screen, this marvel of computing really works best at the heart of something.

That something can be software, of course, such as building a games console with RetroPie and ROMs, but most of what we do with Raspberry Pi is purpose-led. It's fair to say that becoming a Raspberry Pi user usually signals the start of a project or a journey – coding, of course, but most likely with a goal in mind.

Makers being makers, one project tends to lead to another. The following pages will help you kit out Raspberry Pi ready for an existing or planned project and, hopefully, give you some ideas of what that next Raspberry Pi make might be.
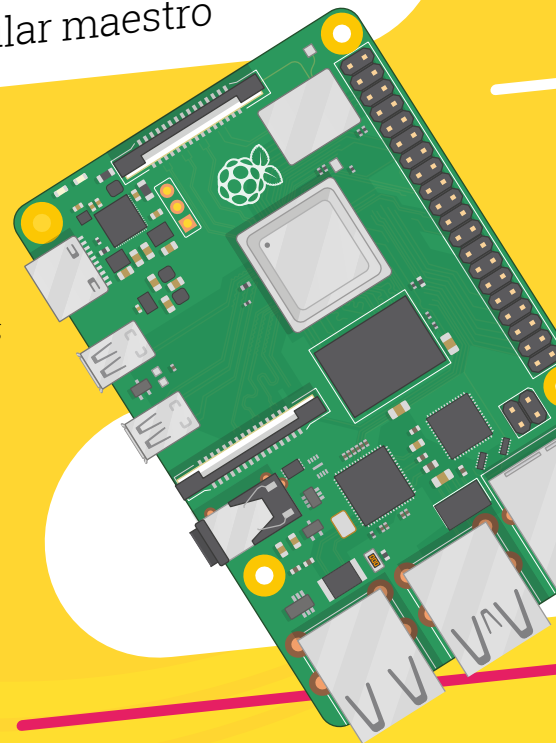
RASPBERRY PI
OFFICIAL KIT

Select smart matching accessories and the latest Raspberry Pi computers

Raspberry Pi Official Case

£5 / $5 magpi.cc/case

Designed by the team at Kinneir Dufort, and sporting the same smart livery as the Raspberry Pi Keyboard and Mouse, the official case comes in versions for Raspberry Pi Zero and for the Model 1 and 3 A+. Cutouts in the case sides provide easy access to the microSD card slot and to the USB, HDMI, and AV ports.

Raspberry Pi 4 Model B

£35 magpi.cc/raspberrypi4

Raspberry Pi 4 comes in configurations from 2GB to 8GB, a brace of USB 2 and USB 3 ports and has a 1500GHz processor powerful enough to run two 4K monitors at once. Gigabit Ethernet, Bluetooth, and 40 GPIO pins to hook up a range of projects. All powered by Raspberry Pi OS. Treat yourself to the flagship single-board computer.

High Quality Camera

£50/ $50 magpi.cc/hqcamera

With a 12.3MP Sony IMX47 sensor and compatible with C- and CS-mount lenses, the High Quality Camera adds serious photography capabilities to your Raspberry Pi retinue. The camera supports RAW image capture and focal lengths of 12.5 mm–22.4 mm.
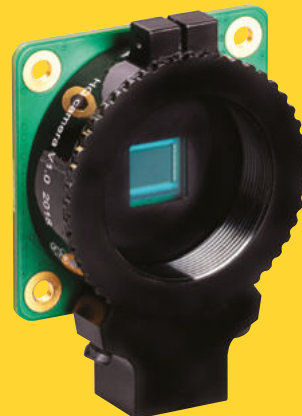
> "Becoming a Raspberry Pi user usually signals the start of a project"

Raspberry Pi Keyboard and Mouse

£16 / $17 magpi.cc/keyboard

£7 / $8 magpi.cc/mouse

Available in smart black or a sleek white finish with a glowing raspberry red underside, the official Raspberry Pi Keyboard doubles as a hub. It sports three USB Type A host ports and a mini USB to connect to your Raspberry Pi. The accompanying three-button Raspberry Pi Mouse has a quick-scroll button for easy screen navigation.

RETRO
GAMING KIT

Gaming, just like you remember it

Pimoroni Picade

£165 / $185 magpi.cc/picade

Playing arcade and computer games from the eighties and nineties is one of the most popular uses of Raspberry Pi. The Pimoroni Picade provides a self-contained tabletop gaming setup: it has an 8-inch or 10-inch IPS 1024×768-pixel touchscreen display and comes with a solid cabinet to assemble from powder-coated panels. Install RetroPie, choose your favourite games, and press play.

PiBoy DMG

£90 / $119 magpi.cc/piboydmg

The £90 PiBoy DMG distinguishes itself from other portable gaming consoles with a superior build quality, tactile buttons, a cooling fan, and the ability to adjust the display brightness. You can play classic games for hours on the move. If you don't fancy the build, an assembled version with Raspberry Pi inside can be bought for $199.
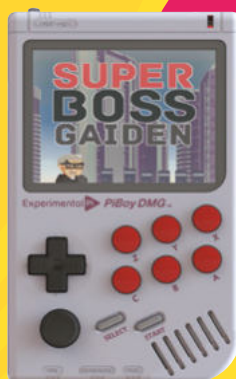
Nes4Pi

£29 / $38 magpi.cc/nespi4

This retro gaming case is ideal for makers who want to build their own gaming console. Lift the cartridge flap at the front to reveal a cartridge which houses a 2.5-inch SSD drive. A fan keeps Raspberry Pi cool during intense gaming action.

COOL CASES

Use these thermal management cases to overclock Raspberry Pi

Argon One

£24 / $35, magpi.cc/argonone

This solid aluminium case is relatively heavy at 180 g, but also has one of the most effective heatsinks for the powerful Raspberry Pi 4 and a power-controlled fan. A daughterboard inside extends the GPIO header and gives Raspberry Pi a dedicated power button. It also repositions the AV and HDMI ports for easier access. A great way to turn Raspberry Pi into a desktop-like solution and our highest-rating non-official case.

Flirc Raspberry Pi 4 case

£16 / $16, magpi.cc/flirc

This £16 case has a smooth milled aluminium top and bottom, and is admirably easy to set up. Pop your Raspberry Pi inside, apply thermal paste, and clip the case halves together, securing with screws at four corners. The metal case acts as a giant heatsink to keep the temperature down.

pi-top [4] DIY Edition

£95 /$100, magpi.cc/pitop4diy

The new case from pi-top turns Raspberry Pi into a portable machine. This pi-top [4] is the only case with a built-in battery and small OLED screen. It also packs a heatsink, fan, and power management. The new £95 DIY option brings the price down, and you get a rugged case built to withstand the classroom environment. A separate touchscreen display and keyboard is incoming.

RASPBERRY PI

HATs

Add a HAT (Hardware Attached on Top) to enjoy funky new features

ModMyPi JAM HAT

£7 / $9 magpi.cc/jamhat

Audible and visual expression with a massive dose of fun, the JAM HAT provides bleeps and buzzers and LED lights once you've successfully completed a Scratch or Python coding project. It's great for kinaesthetic learners, has metal standoffs to insulate it from Raspberry Pi, and comes with a comprehensive guide to encourage independence.

Sense HAT

£30 / $40 magpi.cc/sensehat

Originally designed for the Astro Pi space mission, the Sense HAT helps you explore the world around you and express your findings via its 64-pixel LED grid. Use it to display scrolling text or the basis of a custom clock.

> "Audible and visual expression with a massive dose of fun"
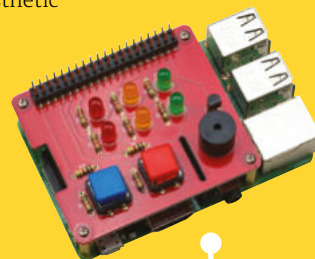
QUIRKY KIT And now for something completely different...

StereoPi

£61 / $79, magpi.cc/stereopi

Stereoscopic video is produced using two cameras to convince a brain you're looking at something 3D. StereoPi is a fantastic 3D video production kit built using a Raspberry Pi Compute Module and two cameras. Live-stream and record real-time stereoscopic video and images using a StereoPi kit.

Grow

£23 / $30, magpi.cc/grow

A self-watering system for your plants that's monitored by Raspberry Pi and the Pimoroni Grow HAT's capacitive sensors should ensure cress, herbs, or chillies you plant this autumn get enough nutrients to sustain them. When they're feeling parched, a built-in piezo buzzer attracts the owner's attention.

Naturebytes Wildlife Cam Case

£40 / $52, magpi.cc/naturebytes

This 3D-printed case is ruggedised so it can survive all weather conditions while fixed securely to a tree or fence. Add a Raspberry Pi and camera to monitor birds, butterflies, and bats and view them remotely while tucked up snugly on your sofa.

Pimoroni Unicorn HAT Mini

£20 / $26 magpi.cc/unicornhatmini

Unicorn HATs are colourful matrices with a refresh rate that's fast enough to display animations. The Mini has a 17×7-pixel matrix and supports pixel shading, as well as scrolling text originating from commands in Python.

Pimoroni Automation HAT Mini

£20 / $26 magpi.cc/automationhatmini

An excellent entry point for home automation, this Pimoroni HAT works with a range of consumer appliances and can be set to turn on lights and heating when preset thresholds are met. It can even water your houseplants if they begin to dry out.

Inky wHAT

£45 / $59 magpi.cc/inkywhat

A Kindle-like e-ink display that works in all light conditions and updates only when prompted ensures this fun HAT draws barely any power. Inky can show off highly detailed, nuanced greyscale images and text. Messages sent to it stay on screen, even if you disconnect Raspberry Pi.

Google AIY Voice Kit 2

£46 / $60 magpi.cc/aiyvoice

A super introduction to artificial intelligence computing, the AIY Voice Kit 2 includes a Raspberry Pi Zero WH, speaker, voice bonnet, buttons, and instructions on how to make your own voice box that uses the Google Assistant.

SOUND & VISION KIT

HiFiBerry DAC2

£89 / $115, magpi.cc/dac2

HiFiBerry DAC2 is a great choice of DAC (digital-audio-converter) to convert digital audio data from your Raspberry Pi GPIO pins to an analogue output. With a DAC, you can connect Raspberry Pi to an external amplifier or receiver and play digital audio on analogue equipment. Use it to make a super-smart audio system.

Pirate Audio

£20 / $26, magpi.cc/pirateaudio

Hack an old radio or speaker with this mini HAT for Raspberry Pi Zero. This diminutive DAC boosts the audio quality of existing amp and speakers, or a monitor, to play 24-bit lossless MP3, FLAC, and WAV files. Pimoroni's own Pirate software supplies album art and playback controls.

Orchard Audio PecanPi DAC

From £212 / $275, magpi.cc/pecanpi

This DAC is crammed full of goodies to excite the serious audiophile alongside a Raspberry Pi 3B and a pair of extremely capable Texas Instruments audio converters. Phono and analogue outputs, 125dB dynamic range, and crisp, detailed music playback.

SmartiPi2 Touch

£24 / $28, magpi.cc/smartipi2

This useful case was designed for use with the official Raspberry Pi 7-inch touchscreen and effectively turns your Raspberry Pi into a (somewhat bulky) tablet with stand. There's room inside to add a Camera Module, a fan at the back, and interchangeable faceplates.

ROBOTS

Embrace our automated future by building your own robot

4Tronix M.A.R.S. Rover

£100 / $130 magpi.cc/marsrover

Six driving wheels – four steerable – and a suspension system based on the real Mars rover might be all the reasons you need to choose this robot. One of the five servos in this complex but rewarding to build kit controls the rotating mast obstacle-detecting sensor.

RockyBorg

£99 / $129 magpi.cc/rockyborg

The joy of RockyBorg is the crazy driving experience that comes from it being a three-wheeler. The high-speed wheelbarrow-like robot vehicle has two 180 rpm motors on its rear wheels and a servo to tilt the whole thing and change direction. Add a Camera Module to capture its madcap driving antics!

SB Components PiArm

£359 / $473 magpi.cc/piarm

An all-metal robot arm with full six-axis movement and LEDs for the servos that light up to indicate how much power is left in them, this is a powerful kit for users keen to explore automation and programming for practical uses. Pick and place, object detection, and drawing are all supported.

CamJam EduKit 3

£18 / $24 magpi.cc/edukit3

An excellent introduction to robotics, the EduKit provides two wheels, a motor, turning ball (as a third wheel), sensors, and line-detectors, leaving you to invent your own robot vehicle chassis. A breadboard and jumper wires help you get started.

INDUSTRY GOODIES

Easy options for using Raspberry Pi in an industrial environment

StratoPi CM Duo

€181, magpi.cc/cmduo

This industrial 10/100 Ethernet server proffers a Compute Module 3+ (Raspberry Pi 3 innards on a tiny PCB that attaches) on a custom DDR2-SODIMM board inside a DIN-rail case. Strato also provides two microSD card slots and two USB-A ports.

Phoenix UCS Universal Housing

From €215, magpi.cc/ucs

If you need to encase an industrial product, UCS's range of modular designs should be a great fit. Robust enough to meet IP40 standards, the three sizes of case have side panels with openings for Raspberry Pi connectors, Torx screws, and adhesive pads.

Build a retro
CD-ROM console

Connect a PC DVD-ROM drive and CRT TV to Raspberry Pi to play original disc games for 1990s computers and consoles

MAKER

K.G. Orphanides

K.G. is a writer, maker of odd games and software preservation enthusiast. They will fight anyone who claims that piracy is the only thing emulation's good for.

@KGOrphanides

Working with original CD-ROMs is critical to software preservation, backup maintenance, and full emulation. This month, we'll add a disc drive to Raspberry Pi 4, connect a TV to make the most of CRT-era graphics, and overclock Raspberry Pi for an emulation performance boost

We'll use this hardware to add disc support to the system we made in our DOS emulation tutorial (see **magpi.cc/dosemulation**) and to emulate early disc-based consoles. We'll also explore the best legal landscape of disc emulation.

This project works best with Raspberry Pi 4 and a freshly installed Raspberry Pi OS (32-bit).

Images, discs, and the law

In the UK, you're not allowed to make copies of software, video, or music discs you've bought (**magpi.cc/ukgovcopying**); there are no exceptions (**magpi.cc/copyexceptions**) for backups or transcoding to play on another platform.

Unlike some PC software, permission to make copies for personal use is never granted in console games' End User License Agreements (EULAs). You have to use the original discs.

More obviously, you can't download disc images that someone else has made (even if you already

own the game) or console operating system BIOS files. This means we'll be restricting ourselves to emulators that can actually play games from disc and which have a High Level Emulation (HLE) BIOS.

This peculiar combination of laws currently rules out a number of normally viable emulation platforms, such as the Amiga CD32, for which BIOS images are legally available via Cloanto's Amiga Forever (**amigaforever.com**), as the emulators that use them expect you to work with CD ISOs rather than original discs.

Similarly, although the RetroArch Disc Project (**magpi.cc/retroarchdisc**) is doing fine work on introducing disc support to certain Mega CD, Saturn and 3DO emulators, most of the emulators that currently have real disc support require BIOS images that you won't be able to legally obtain in the UK.

Read on, though, because that still leaves a few disc-based gaming platforms you can bring back to life with Raspberry Pi.

> **"** This project is an excellent use for any old PC CD or DVD drives you might have **"**

Disc support

USB disc drives and Raspberry Pi can be an awkward combination. Modern bus-powered drives often use dual power/data USB connections that require more power than Raspberry Pi can readily supply, and don't play nicely with USB hubs or external 5V power adapters.

Emulation adds to these problems, as early consoles often expected the disc to be spinning at all times, which many portable USB disc readers are unhappy with. Similarly, avoid Blu-ray drives: their spin and spin-down speeds frequently don't mesh well with the expectations of emulated consoles.

▲ Early DOS CD-ROM games like Conspiracy were designed to run directly from the disc

Warning! CRT

Cathode-ray tube television sets can be dangerous to repair. Be careful if opening up a CRT device.

magpi.cc/crt

This system can play DOS CD-ROM titles from disc as well as original games

If you want to make the Disc System more portable, the SATA DVD drive can be mounted in a drive enclosure instead of connected via an adapter. Make sure it's mains-powered

They aren't essential, but a cooling case and controller are useful additions to this build

A standard internal DVD-ROM drive is perfect: this build used a 2008 Sony NEC Optiarc AD-7203S SATA DVD-RW. Drives in this range are widely available for around £15, and this project is an excellent use for any old PC CD or DVD drives you might have lying around.

To connect it, you'll need either an external disc drive enclosure or SATA to USB adapter that takes external mains power. The kit photo above shows a StarTech USB2SATAIDE, which also supports IDE CD-ROM drives and hard disks. While this adapter is a little pricey at £42, similar hardware can be bought for about £20.

01 Connect your disc drive

Plug the SATA data and power connectors of your adapter into the back of your DVD-ROM drive, plug the adapter's USB connector into Raspberry Pi, and its mains adapter into a plug socket or power strip.

This also works with externally powered drive boxes, which look better if you want a tidy and portable final product, but will require a little more assembly to the tune of a few screws.

02 Overclock Raspberry Pi (Optional)

Emulation can be demanding, so GPU and CPU overclocking makes sense, although it's not absolutely necessary for this project. In a Terminal, type:
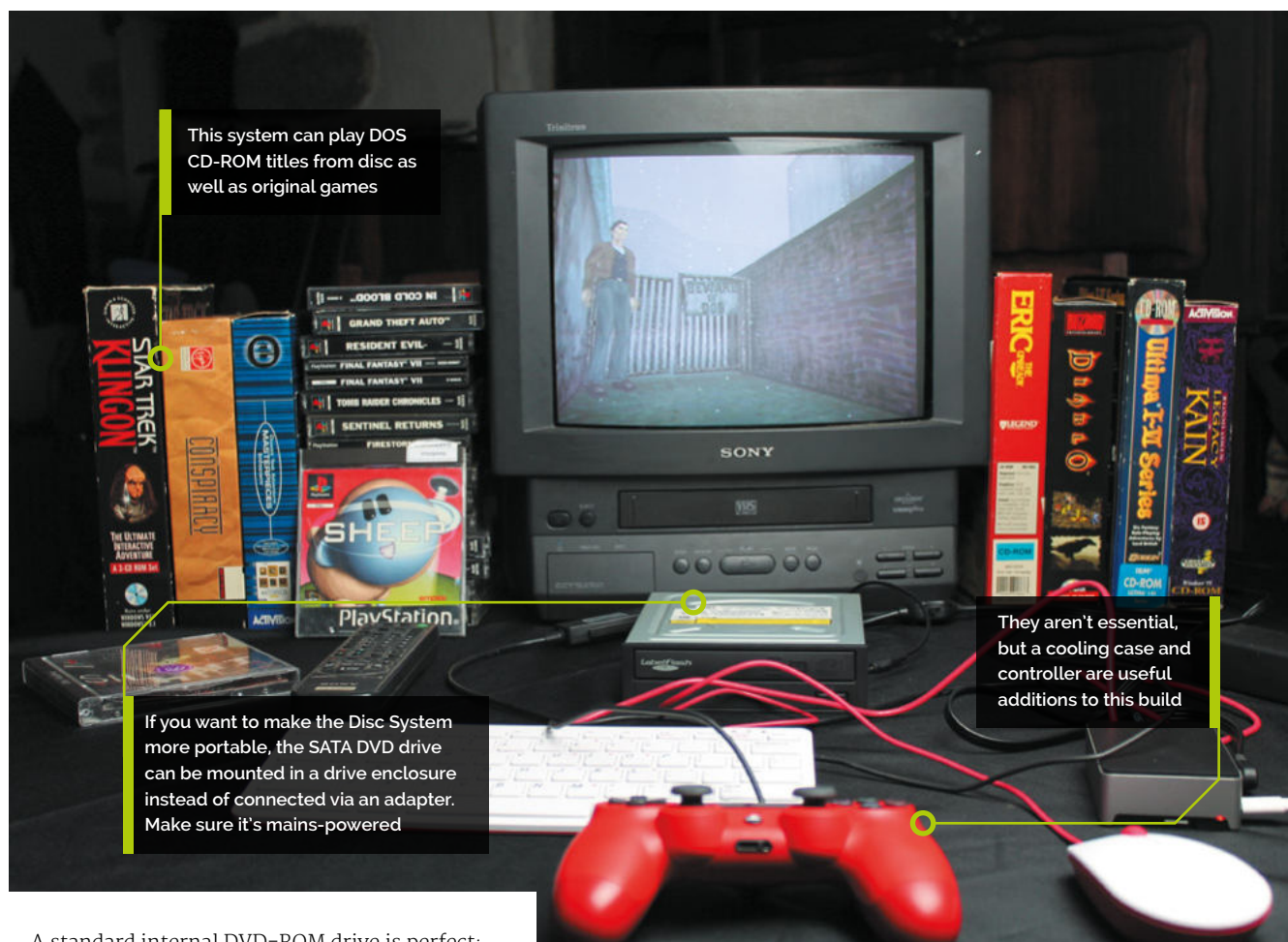
```
sudo mousepad /boot/config.txt
```

And add the following lines:

```
over_voltage=6
arm_freq=1750
gpu_freq=700
```

These were stable during testing, but if Raspberry Pi fails to boot, power-cycle it and hold down **SHIFT** to boot into recovery mode. Then knock the settings down a bit. See **magpi.cc/overclock** for further information on overclocking Raspberry Pi 4.

If you overclock, you should use a stand or, better still, an active or passive cooling case. A FLIRC Raspberry Pi 4 Case worked well here (**magpi.cc/flirc**).

You'll Need

> Full-sized internal desktop DVD-ROM drive

> Mains-powered SATA to USB2 adapter or drive enclosure

> Optional: Active or passive cooling Raspberry Pi case

> Optional: CRT TV

▲ The source code may be lost forever, but you can still play Silent Hill in its original glory – complete with tank controls

▲ To control fixed-path disc mounting for DOSBox using pmount, you'll have to disable the File Manager's default volume management behaviour

03 Enable OpenGL

We'll want OpenGL support for some emulators, such as PCSXR, In a Terminal, enter `sudo raspi-config`. Select Advanced Options > GL Driver > GL (Fake KMS), then exit and allow the system to reboot.

Open **/boot/config.txt** and make sure the following option is present and not commented out:

```
dtoverlay=vc4-fkms-v3d
```
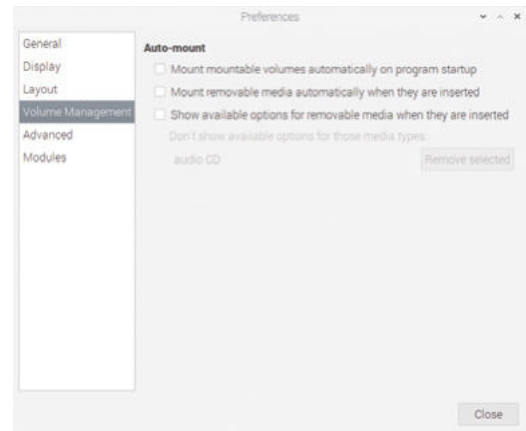
04 Drop your resolution

Dropping your display resolution is an easy way of improving emulator performance. If you're using a standard 1920×1080 widescreen monitor, you won't need that resolution to play older games.

Open the menu and go to Preferences > Screen configuration and set your resolution to 720×576 (or 640×480) if you either have a 4:3 display or can live with a bit of screen stretching in exchange for smooth full-screen graphics. Choose 1280×720 if you don't mind playing in a window on emulators that can't do aspect ratio correction.

05 Connect an elderly TV (Optional)

A 4:3 aspect ratio display is ideal here, and older display tech has the edge for 1990s console and computer games, too.

Using a CRT TV rather than a modern LCD flatscreen can improve graphical quality as sprite and even 3D graphics of the era were optimised to work with the display artefacts of CRT.

Raspberry Pi supports composite video out. Connect a 4-pole 3.5 mm AV cable to the 3.5 mm port on Raspberry Pi and connect the other end to your TV. Using a composite to SCART adapter can improve picture stability.

Note that Raspberry Pi's 4-pole connector expects video to be connected to the sleeve and ground to ring 2, so ensure that you use a fully compatible cable (**magpi.cc/monitorconnection**). The wrong cable selection can result in non-functional sound, misordered cables, or even damage to your hardware.

> ❝ Dropping your display resolution is an easy way of improving emulator performance ❞

06 Output composite video (Optional)

If you're using a typical 4:3 PAL TV, make the following changes to **/boot/config.txt** to correctly position your display – small alterations may be required for different models.

```
disable_overscan=0
overscan_left=16
overscan_right=16
sdtv_mode=2
```

Quick Tip 👍

Clean your discs

The condition of discs can lead to choppy sound and video identical to a disc drive that's spinning too fast for the emulator, so use a clean, unscratched game while testing.

In a Terminal, enter `sudo raspi-config`, then go to Advanced Options, Pi 4 Video Output, and Enable analogue TV output. Finish and reboot.

07 Mount a CD in DOSBox

If you've been following these tutorials, you may already have DOSBox or DOSBox-X installed. If not, at a Terminal:

```
sudo apt install dosbox
dosbox
```

To mount a disc at the DOS prompt, type:

```
mount D /media/YourDiscName/ -t cdrom -usecd
0 -ioctl
```

To unmount a disc in DOSBox, type:

```
mount -u D
```

By default, each individual disc has to be manually mounted in DOSBox, as mount point names are automatically generated based on the volume name of the disc. This can be a problem if you need to swap DOS CDs during play or installation.

08 Create a fixed mount point

To work around this, we can use the `pmount` command. From the Terminal, let's first make sure it's installed and then configure it:

```
sudo apt install pmount
sudo mousepad /etc/pmount.allow
```
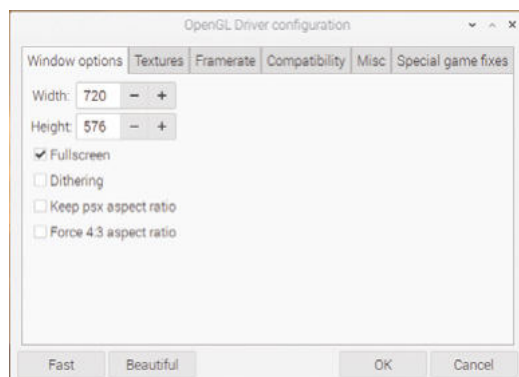

▲ If you're going to be playing on a PAL CRT television, you'll need a 720×576 full-screen resolution

Add the following line to the file, then save and exit:

```
/dev/sr0
```

On the desktop, open File Manager. Go to Edit > Preferences > Volume Management and untick all the Auto-mount options. Reboot Raspberry Pi.

09 Mount and swap CDs

Now, to mount a disc, insert it, open a Terminal window and type:

```
pmount /dev/sr0
```

To unmount it:

```
pumount /dev/sr0
```

Repeat the first `pmount` command to mount a new disc. Now, every disc will have a fixed mount point of **/media/sr0/**. This means that, in DOSBox, you'll just need to mount **D /media/sr0/** once.

When you want to swap discs, whether at the DOS prompt or in-application, hop over to a Linux Terminal window, run through the `pmount` commands and then, back in DOSBox, press **CTRL+F4** to update cached information about your mounted drives.

10 Play original discs

PCSXR – the R stands for either Reloaded or ReARMed, depending on which version you're using – is an open-source emulator.

◀ Getting PCSXR's disc drive settings right is critical. Too high a speed or too fast a spindown can make games judder and stutter
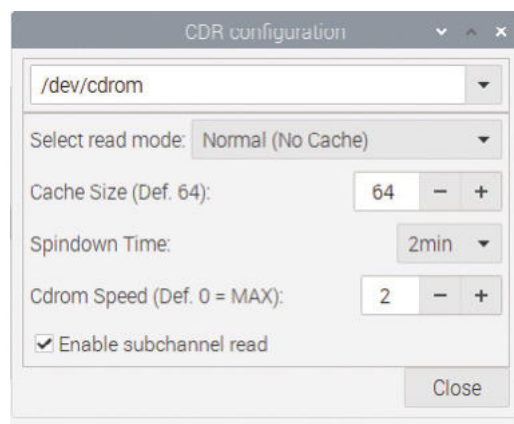
Quick Tip 👍

Composite Zero

Raspberry Pi Zero lacks its siblings' composite video out port, but instead has a TV header which you can use to connect an RCA cable. For detailed instructions, see **magpi.cc/rcapizero**.

▲ This build included an internal PC DVD-ROM drive, an externally powered SATA-to-USB adapter, a composite video out cable and SCART adapter, a heat-sink case, and controller

It also has a genuinely good emulated bios, so you don't need to download anything dodgy to make it work. The desktop version works best for original discs. Open a Terminal and type:

```
sudo apt install pcsxr
```

It can run games including Final Fantasy VII, Silent Hill, GTA, Sheep, and Resident Evil either perfectly or with only minor errors, but you'll have to adjust some settings first.

11 Configure PCSXR's graphics

Go to the Configuration menu and select Plugins & BIOS. From the Graphics pull-down, select OpenGL Driver 1.1.78. Click on the window icon directly to the right of the pull-down.

Starting with the Windows options tab, assuming you're using the PAL resolution we configured, enter a width of 720, a height of 576, and tick the Fullscreen box. On the Textures tab, set Quality to Don't care, Filtering to None, and HiRes Tex to None.

In the Framerate tab, ensure that 'Use FPS limit' is ticked and set to auto-detect. Moving to the Compatibility tab, select Standard offscreen drawing, a Black framebuffer, and Emulated Vram

for framebuffer access. Make sure the Mask bit and Alpha multipass boxes are ticked.

In the Misc tab, tick Untimed MDECs, Force 15 bit framebuffer updates, and Use OpenGL extensions. The 'Special game features' tab includes game-specific options, such as battle cursors for Final Fantasy VII. Click Okay to save your changes.

12 Configure PCSXR's sound and CD-ROM

Click on the window icon next to the Sound pulldown in the configuration window. Set Volume to Low, Reverb to Off, and Interpolation to None. Unsick everything except Single channel sound. Click Close, then open the CD-ROM settings.

Set read mode to Normal (No Cache), Spindown time to 2 minutes, Cdrom Speed to 2min, and tick Emulated subchannel read.

While you may need to adjust these settings for individual games or experiment with higher resolutions, this combination allows the vast majority of titles to run reasonably smoothly from their original discs.

To test this, insert a disc into the drive, wait for it to load, then click on the CD icon at top left of the PCSXR window. M

Quick Tip 👍

Stand it up

If you don't have a cooling case, you can increase airflow around Raspberry Pi by using a stand to support it on edge.

Part 01

Build a Home Assistant with Raspberry Pi

Is your house boring? Smarten it up with free home automation tools and Raspberry Pi

MAKER

PJ Evans

PJ is a writer, software engineer, and tinkerer. He just wants to start his coffee machine on the first morning yawn.

@mrpjevans

Home automation is one of Raspberry Pi's success stories. Our small friend is the perfect orchestrator of many devices around the home. The cost of implementing smart devices such as lights and sensors has fallen significantly over the past few years.

Nevertheless, many have concerns about subscription costs and privacy of the data collected. The good news is that many open-source Raspberry Pi automation systems have matured significantly over the past few years. They now challenge the big players, are free of charge, and put your privacy first. Over the next three issues we're going to set up a smart home from scratch.
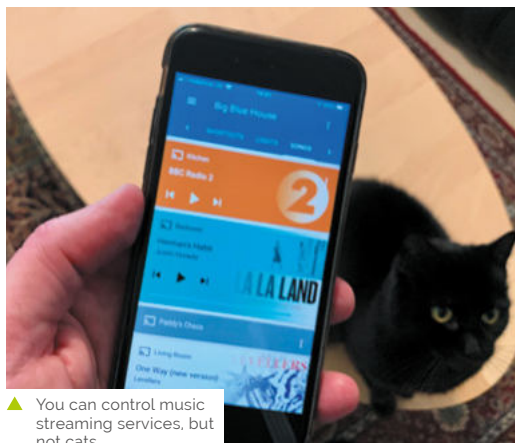
▲ You can control music streaming services, but not cats

Top Tip 👍

Extra features

Home Assistant integrations can often unlock extra features, such as more colour options in Ikea smart lights.

01 Your new Home Assistant

To make our home a more fun place to be, we're going to set up a home automation system. This is software that can communicate with multiple devices and make changes to your environment based on a rule set. Sounds a bit complicated, but the 'HA' scene has got a lot more friendly over the past few years. We've chosen the appropriately named 'Home Assistant' (**homeassistant.io**) because it is a complete operating system package and runs well on Raspberry Pi 3 or above. Best of all, it has incredible support for hundreds of smart devices.

02 Installation and first boot

Home Assistant is available as a full microSD card image – no operating system installation is required in advance. To get the image, go to **magpi.cc/homeassistantio**. Make sure you pick the right one because different images are available for Raspberry Pi 3 and 4. Once downloaded, burn the images to a microSD card using Raspberry Pi Imager (**magpi.cc/imager**). We strongly recommend using a wired Ethernet connection for reliability. Whichever you choose, use a wired connection when booting up for the first time. Be patient, Home Assistant will take up to 20 minutes to start up on first boot.

Lights can be controlled individually or as a group to create unique effects

Home Assistant runs in your browser or as a smartphone app

03 Terminology

Before going any further, it's useful to understand the terms used in Home Assistant.

Take a look at the 'Home Assistant terms' box in order to better understand Integrations, Devices, Entities, and Areas.

Take some time to become familiar with the terms while Home Assistant is setting up.

Home Assistant terms

These are some of the terms you'll need to know in Home Assistant.

- **Integrations** are software modules that allow Home Assistant to talk to different platforms such as Philips Hue or Nest. There are hundreds available and you can write your own in Python.
- **Devices** are single items that are exposed by integrations, e.g. a printer.
- **Entities** are individual measurements or controls; for example, each different type of sensor on a weather station.
- **Areas** are useful ways of grouping devices and entities, normally referring to a room in your house.

There's more, but that's enough to start with.
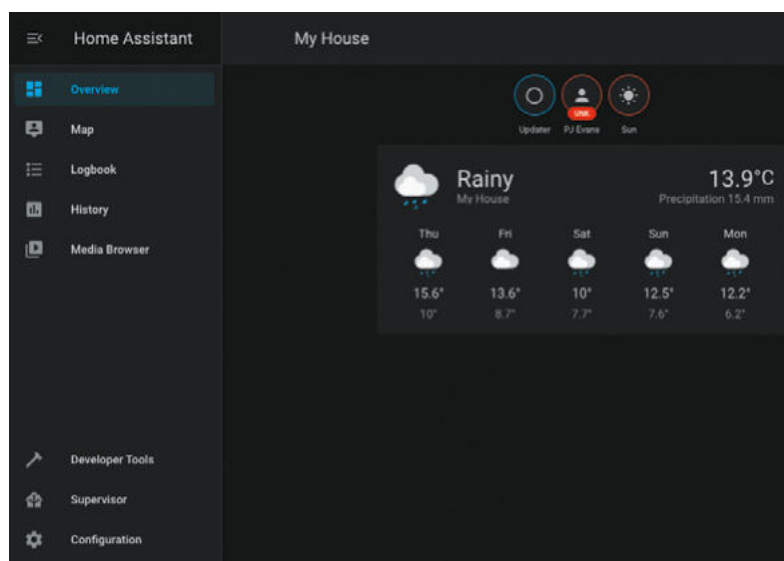
▲ The default overview shows you weather and sunrise times. These can be used to trigger events
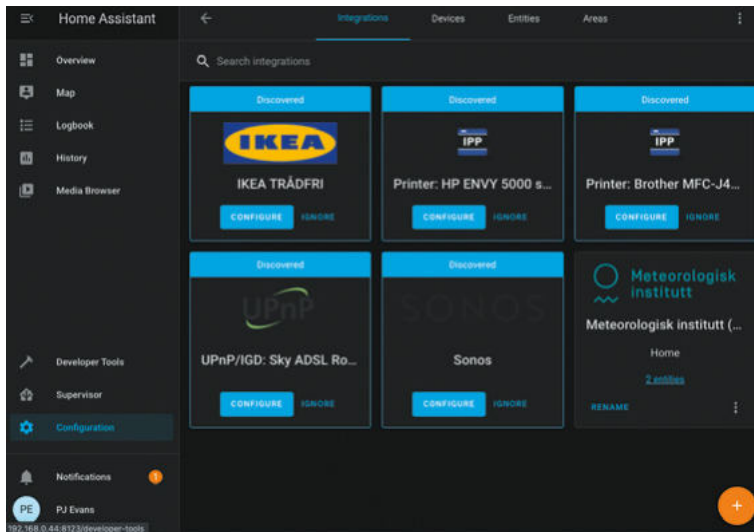
▲ On installation, Home Assistant will attempt to discover smart devices on your network. You may be surprised how many devices are available
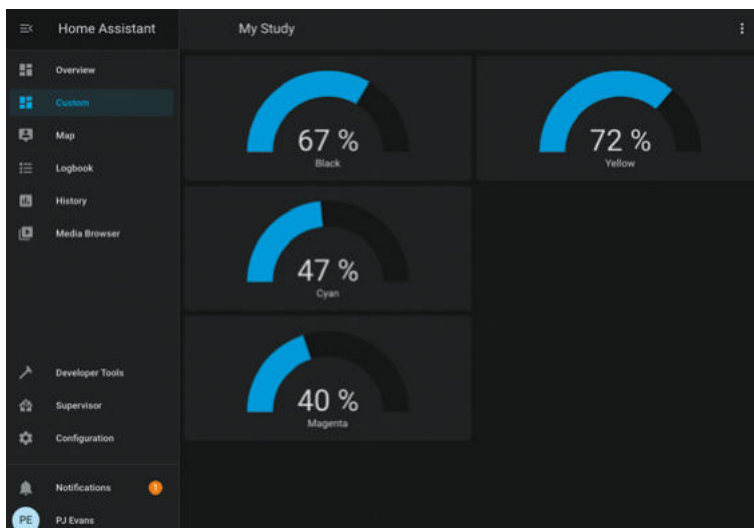
▼ Using custom panels, we can provide a clear view of our printer's ink supply

04 First connection

After 20 minutes (don't worry, it's a one-time thing), you should be able to see a welcome screen. Open a web browser and visit: **http://homeassistant.local:8123/**.

If not, try using a network utility like Fing for iOS or Android to locate the IP address of the server and try that instead. If you still can't get a connection, try waiting a little longer. Eventually, you should see a 'Preparing Home Assistant' screen. This will shortly change to an account creation screen.

Home Assistant has full support for multiple accounts with different permission levels. The account you create here will have full control over the system.

05 Initial settings

Once you've completed the form and created your first account, you will be asked to select your location and give it a name. This information never leaves your network and is used to get information on sunrise and sunset times for where you are. You can also choose your preferred unit of measurement. These details can be changed at any time. You'll now be taken to the Overview dashboard, the heart of the system. A dashboard is a collection of panels that display various bits of information and allow you to control your environment. Your system is already up and running.

06 Your first dashboard

The Overview dashboard has been populated with some initial panels. Largest is the weather panel, based on your location. You will also see 'badges' at the top. Try clicking on the Sun badge for data about today's sunrise and sunset. There will also be a person badge which will probably say UNK for 'unknown'. We'll come to that later. For now, explore the left-hand menu. You can see a map (this will get more useful), a log of all events, and several configuration options. You'll also see Notifications – the chances are, you'll have one waiting. If you do, Home Assistant has discovered things on your network that it can talk to.

> ❝ Printers, routers, and media systems will all happily introduce themselves to Home Assistant ❞

07 Your first integration

Did you click that notification in Step 5? If so, you've probably been informed that Home Assistant has already found some devices on your network. It can be surprising how chatty some things can be. Printers, routers, and media systems such as Sonos will all happily introduce themselves to Home Assistant. To actually start using the integrations, click on Configuration then Integrations. Now click Configure on your choice of integration. Some additional information may be required, but often auto-discovered integrations work out-of-the-box. If a particular integration is not of interest to you, click Ignore to hide it.
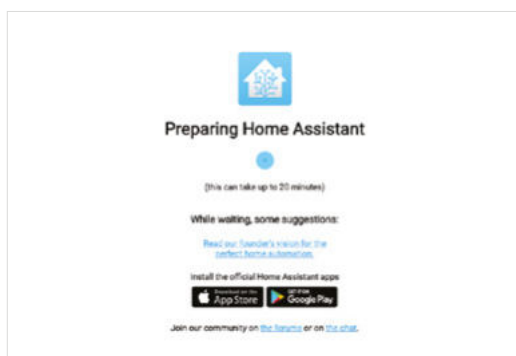
08 Automatic dashboards

Once you've enabled and configured some integrations, go back and have a look at the Overview dashboard. Home Assistant will have automatically added an appropriate panel to show data or add controls. If you have a Philips Hue or Ikea Trådfri gateway, your lights will have been discovered and added to the panel. This feature makes getting started with Home Assistant a breeze. If you're happy with this, you can let Home Assistant update and configure your panel as you add new integrations and devices. However, if you want full control, you can disable this feature and create your own panels.

09 Your own dashboard

When we installed our Home Assistant, it found our networked printer and created a panel that showed the ink levels for each cartridge. It's a bit dull, so let's make a better one. By clicking on the three dots at the top-right of the screen, we can Configure the UI. You'll see a warning that automatic configuration will be disabled. You can now edit, move, delete, and add new panels. You can also add tabs across the top and you can have as many dashboards as you like. We created a new tab for our printer.

10 Adding panels

We now have a nice, clean area to work with. Click the + icon at the bottom-right to add new panels. You will see all the default panels available, covering many different use cases. These include switches, gauges, playback control for media centres, and many more. You can even design your own. We clicked the 'gauge' panel as that seemed best for printer ink. Home Assistant is helpful enough to work out what entities are best for the type of panel and you can control certain aspects such as warning thresholds. We added a gauge for each of our printer ink cartridges.

11 Adding new integrations

We strongly recommend spending some time looking at the available integrations. Click on Configuration, Integrations, then click the + icon. You will be presented with a bewildering list of possibilities. We found an integration for pi-hole, the ad-blocking service. After entering the address of our Raspberry Pi 4 running the service, we had a panel full of stats to look at. Some integrations increase the capability of Home Assistant to talk to other devices. For example, the MQTT (Message Queuing Telemetry Transport) integration allows Home Assistant to subscribe to MQTT topics and trigger events. If you're handy with Python, you can create your own custom integrations too.
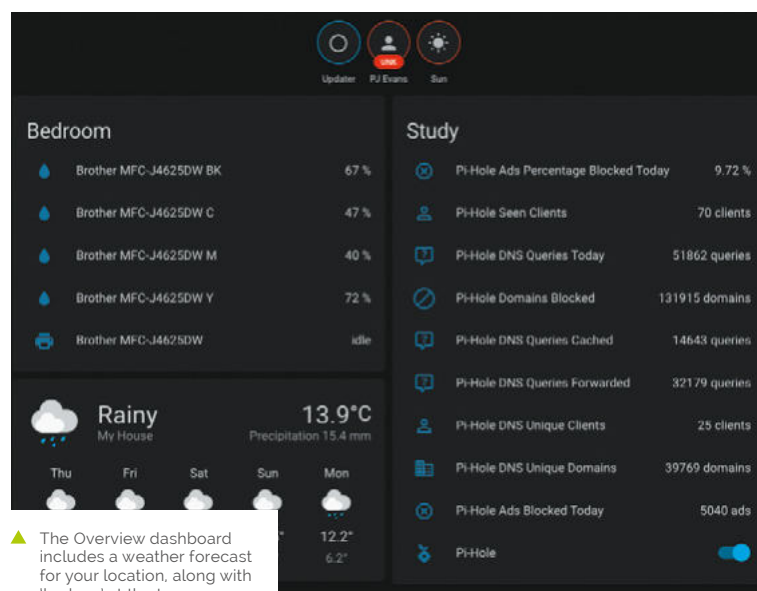
12 Going mobile

If you've set up all your lights to work with Home Assistant, it's going to be a bit pointless if you have to run to a computer every time you need to flick a virtual switch. An essential part of any Home Assistant setup is the smartphone app (iOS or Android). This not only allows you quick access to your dashboards, but also adds you as an entity. The app communicates with Home Assistant and provides location and activity information. All your health stats tracked by your phone can be added and your location reported. All this data stays in your network and you can switch it off any time, but there are great possibilities that we'll look at next month. ◾

◄ Home Assistant can take up to 20 minutes to boot first time, so go and make a cuppa

Top Tip 👍

Back it up!

Home Assistant setups can get complicated. Luckily, you can download a system backup in one click. Make sure you do!

▲ The Overview dashboard includes a weather forecast for your location, along with 'badges' at the top

Part 07

High Quality Camera:
Make a spy camera
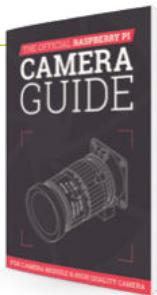
Set up a motion-activated spy camera in your room

We've all been there. You've gone out for the day and you know you closed your bedroom door, but you come back and it's slightly ajar. Who's been in there? Were they friend or foe? In this tutorial, we'll use the Camera Module or HQ Camera as a spy camera that takes a picture when anyone's presence is detected by a passive infrared (PIR) sensor. Here, we're using a Raspberry Pi Zero – which is easier to hide away due to its size – with a special camera cable for it, but you can use any Raspberry Pi model. Unless you want to power it from the mains, you'll also need a portable power supply such as a mobile phone battery pack.

The Official Raspberry Pi Camera Guide

For further tutorials on how to use your HQ Camera or Camera Module, take a look at our new book, *The Official Raspberry Pi Camera Guide*. Its 132 pages are packed with essential info and a range of exciting projects. **magpi.cc/cameraguide**

01 Getting started

First, connect your Camera Module or HQ Camera to Raspberry Pi. Note that if you're using a Raspberry Pi Zero, you'll need a special adapter cable since its camera connector is smaller: the cable's silver connectors should face the Raspberry Pi circuit board. You'll also need to have enabled the camera in the Raspberry Pi Configuration tool's Interfaces tab.
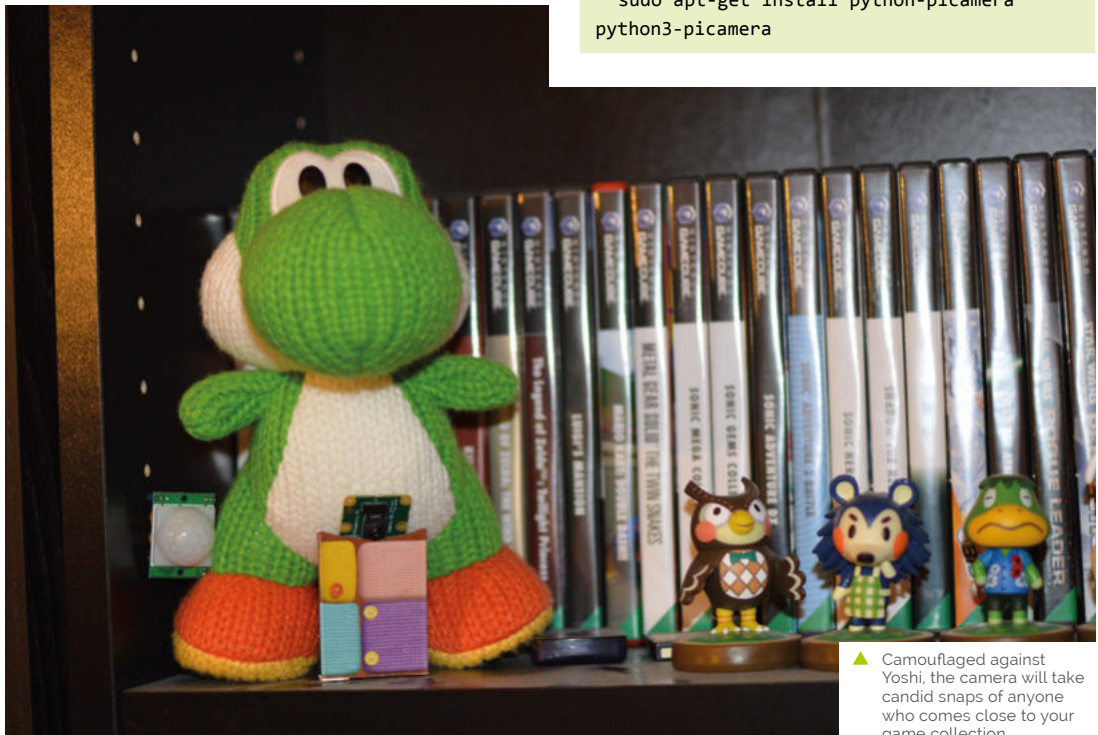
We'll be using the picamera Python library to trigger our spy camera, so if you haven't yet installed it, open a Terminal window and enter:

```
sudo apt-get update
sudo apt-get install python-picamera
python3-picamera
```
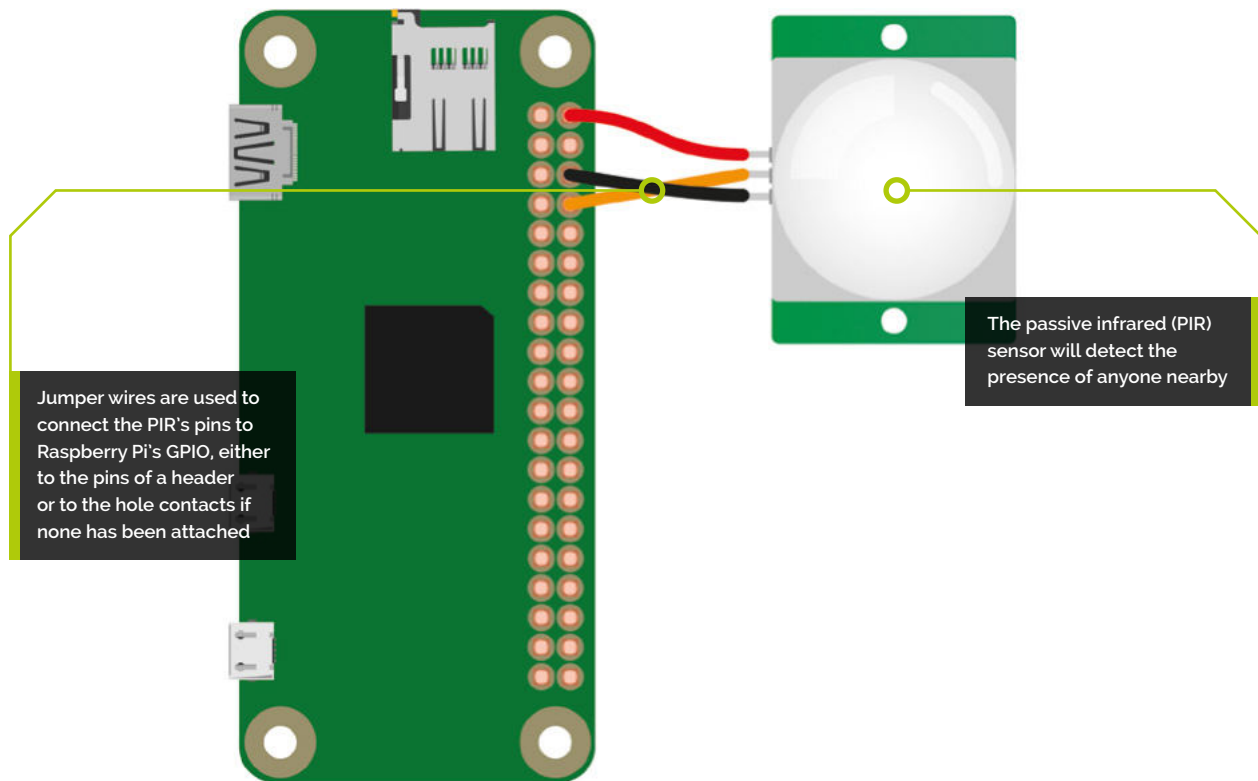
▲ Camouflaged against Yoshi, the camera will take candid snaps of anyone who comes close to your game collection

Figure 1

Jumper wires are used to connect the PIR's pins to Raspberry Pi's GPIO, either to the pins of a header or to the hole contacts if none has been attached

The passive infrared (PIR) sensor will detect the presence of anyone nearby

02 Wire up the circuit

The circuit for this is fairly simple, especially as the PIR does not need a resistor as part of its setup. The PIR comes with three connection pins: VCC, GND, and OUT. If you can't find their labels on the bottom of the sensor, lift off the plastic golf-ball-like diffuser and you should see them on the top of the board. VCC needs to be connected to a 5 V power pin, GND needs to go to a ground pin, and then there's the OUT wire which will be our input. We're connecting it to GPIO 14.

If your Raspberry Pi Zero has GPIO pins attached, you can use female-to-female jumper wires to make the connections, as shown in **Figure 1**. Otherwise, you can loop the wire around the GPIO holes and use a bit of putty to keep them in place, or a dab of glue from a glue gun on a low setting. Soldering is an option if you want to create a permanent spy camera device.

03 Write the code

Now we've got it all wired up, it's time to start coding our spy camera. In the Thonny code editor, create a new file and enter the code from **listing1.py** (overleaf). This script uses two libraries: GPIO Zero and the standard picamera library. GPIO Zero can be used to get a reading from the PIR motion sensor very easily, which can then be tied into the picamera code so it takes a photo when motion is detected.

" Soldering is an option if you want to create a permanent spy camera device "

At the top, we import `MotionSensor` from GPIO Zero and `PiCamera` from picamera. Since we'll be giving each photo a timestamp, we also import `datetime`, along with `sleep` from the `time` library.

In a never-ending `while True:` loop, we use GPIO Zero's handy `wait_for_motion` function to pause the code until the PIR detects any motion. When it does, we set the photo file name to the current time and date, then take the picture. To enable the PIR to settle, we sleep for five seconds before returning to the top of the loop to wait for motion again.

You'll Need

- Camera Module / HQ Camera
- PIR sensor **magpi.cc/pir**
- Raspberry Pi Zero camera cable (optional) **magpi.cc/zerocamcable**
- Portable power supply (optional)
- Jumper wires

04 Final preparations

You can run the code first to give it a test. You might want to change the sensitivity and/or trigger time, which you can do by adjusting the little orange potentiometer screws on the side of the PIR board: Sx adjusts sensitivity, while Tx alters the trigger time.

Once that's done, we'll get the program to start automatically when we boot up the Raspberry Pi. To do so, open up a Terminal window and edit the profile config file with `sudo nano /etc/profile`. To the bottom of the file, add this line:

```
sudo python spy.py
```

In addition, to get Raspberry Pi to boot up slightly faster and, more importantly, to use a little less power so your battery lasts longer, it's best to get it to boot directly to the command line rather than booting to the desktop. The easiest way to change this is to open Preferences > Raspberry Pi Configuration from the desktop; in the default System tab, change Boot to the 'To CLI' option. Alternatively, open a Terminal window and enter `sudo raspi-config` to open the Configuration Tool; select Boot Options > Desktop / CLI and option B2 – Console Autologin Text console.

❝ Hiding your Raspberry Pi and battery behind a plush toy or photo frame can work well ❞

05 Hide your camera

Now you need to find a good place to hide your camera. The default cable for the camera is limited by length, while the PIR can have its wires lengthened, so keep that in mind when building your system. Alternatively, you could get a camera extender (**magpi.cc/camextender**) to link your cable to a standard-width one. Longer standard-width cables – of up to 2 m – are also available if you are not using a Raspberry Pi Zero.

Hiding your Raspberry Pi and battery behind a plush toy or photo frame can work well (you could even put a dummy photo up and cut a hole in it for the camera to look through). The PIR has quite a wide range, so put it up high where people are unlikely to look.

06 Check for intruders

All you need to do now is plug in the power supply and your Raspberry Pi Zero will turn on and automatically run the script. Do some tests to make sure the camera is facing the right way. Leave it running during the day and then when you get back, plug it into a monitor, stop the script, and run `startx` to get the GUI up. From here you can see the pictures it has taken: crucial evidence to catch your dog or sibling red-handed. M

listing1.py

> Language: **Python 3**

DOWNLOAD THE FULL CODE:
magpi.cc/github

```python
001.    #!/usr/bin/env python
002.
003.    from gpiozero import MotionSensor
004.    from picamera import PiCamera
005.    from time import sleep
006.
007.    sensor = MotionSensor(14)
008.    camera = PiCamera()
009.
010.    while True:
011.        sensor.wait_for_motion()
012.        filename = datetime.now().strftime("%H.%M.%S_%Y-%m-%d.
013.    jpg")
014.    camera.capture(filename)
015.    sleep(5)
```
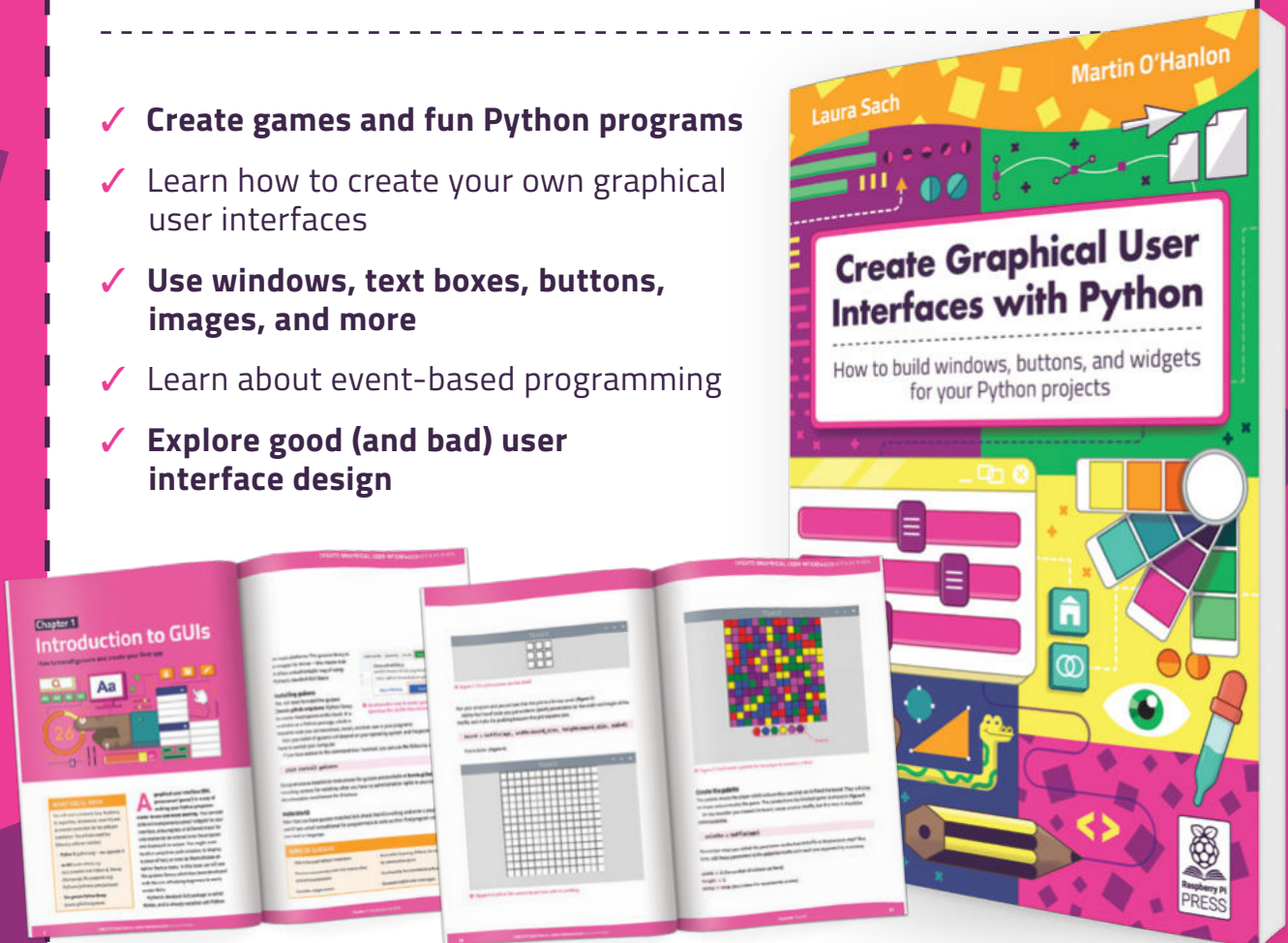
Tap-an-LED:
client add-on board

Add a MIDI client interface board to your touch-sensitive LED matrix

MAKER

Mike Cook

Veteran magazine author from the old days, writer of the Body Build series, plus co-author of *Raspberry Pi for Dummies*, *Raspberry Pi Projects*, and *Raspberry Pi Projects for Dummies*.

▶ **magpi.cc/mikecook**

You'll Need

▶ The hardware from *The MagPi* #97 **magpi.cc/97**

▶ An Arduino Pro Micro board **magpi.cc/promicro**

▶ Free 90-day trial of the full Ableton Live suite (optional) **ableton.com**

Tap-an-LED brings you a touch interface on top of a 16×8 multicoloured LED matrix. We've seen how to build it and program it. Now we look at how to extend it by building a MIDI client interface board.

01 All USB devices are not the same
Many people tend to think you can plug any USB device into any other, but this is not strictly true. The sort of USB connector on a Raspberry Pi computer is USB-A. This connector is always used by a USB host device, like a computer. A host device supplies power and is in control of the process of communicating with the other sort of device, a USB client device. If a client wants to pass information to a host, it has to wait until it is asked by the host if it has anything to say.

02 Interconnectivity
You can't plug a host into a host, nor can you plug a client into a client. Quite simply, the connectors on the USB cable will stop you doing this – even if you make up a special cable. It simply would not work. So, while it is fine for a Raspberry Pi computer to connect with a MIDI sound module, you can't connect it to a DAW (digital audio workstation) like Reaper or Ableton running on another Raspberry Pi computer or other laptop. This limits the role your Raspberry Pi computer can play in a MIDI system.

03 Solving the problem
You could use a MIDI interface cable on both computers and connect the MIDI sockets up with a couple of MIDI leads, but we have found this seldom works because of the accuracy of the
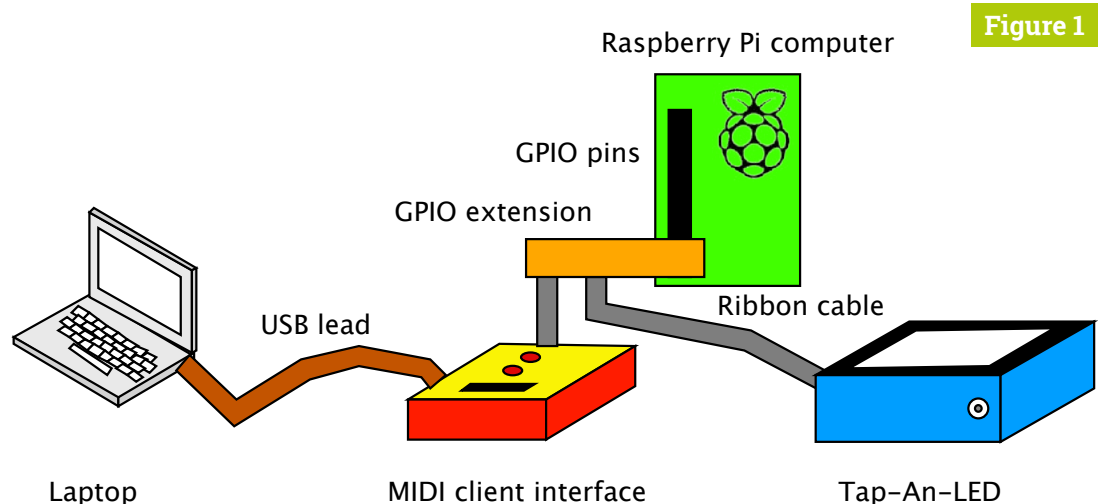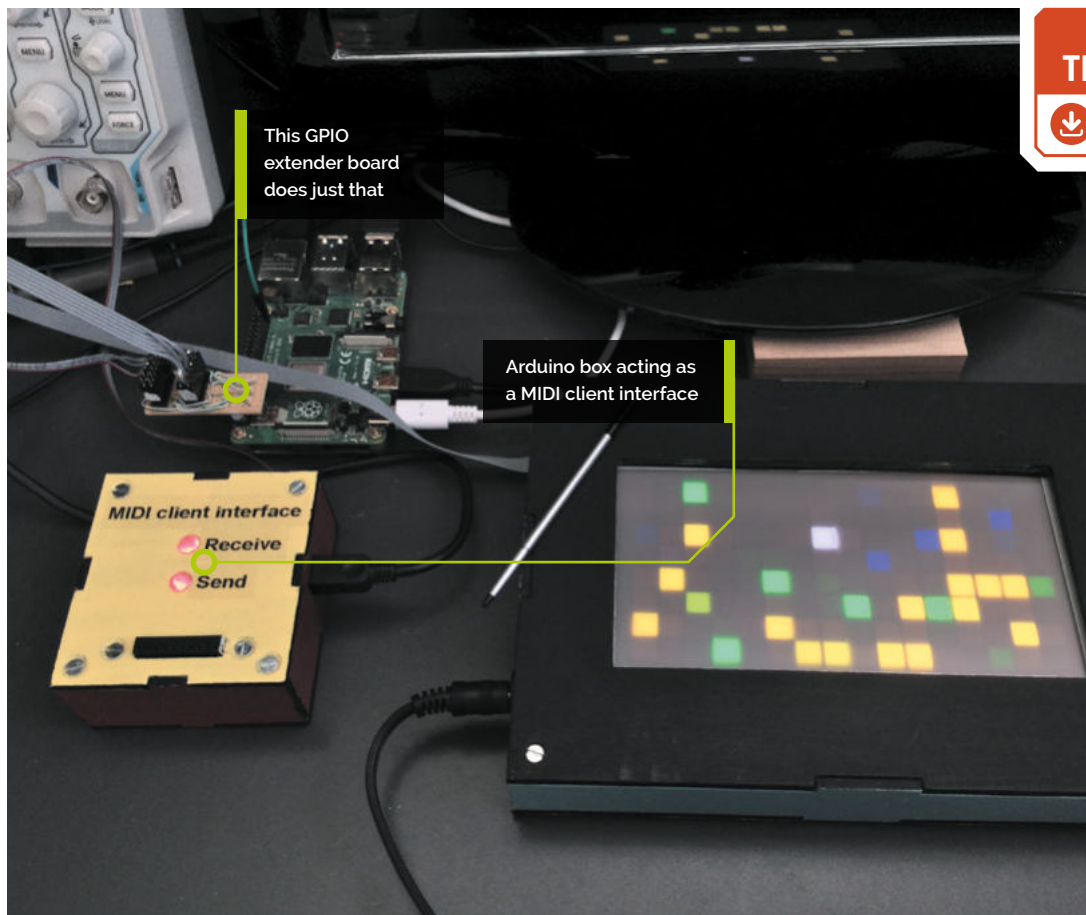
Figure 1

Raspberry Pi computer

GPIO pins

GPIO extension

Ribbon cable

USB lead

Laptop

MIDI client interface

Tap-An-LED

▶ **Figure 1** Block diagram of complete system

This GPIO extender board does just that

Arduino box acting as a MIDI client interface

MIDI client interface
Receive
Send

Top Tip 👍

Using Arduino I/O

The analogue inputs are useful for attaching potentiometers to act as controller inputs, and you can even add multiplexers to connect more potentiometers. So the nine analogue inputs, each with an eight-to-one multiplexer, could handle 72 potentiometers.

baud rate produced by these interface leads. So, we have come up with a solution to get round this by enlisting the help of an Arduino, like we have done in the past. But this time we will be using a different sort of Arduino, the Pro Micro, based on the ATmega32U4 chip. We get the bonus of using the Arduino's peripherals as well.

❝ We made a little 12-pin GPIO extender board ❞

04 How does this work?

The idea is that the Arduino presents a USB MIDI client interface to a host and then we can communicate with it from the Raspberry Pi computer using its serial port. This can be at a fast rate, and we are not faced with the problem of trying to get the serial port to use MIDI speeds, which are not directly supported. The block diagram of this project is shown in **Figure 1**. While we could wire the Arduino to the same cable as our Tap-An-LED box, we did not want two boxes permanently joined together with a common flying lead.

05 Making the GPIO connector

To get round this, we made a little 12-pin GPIO extender board so that we could use the two boxes together. This is simply a piece of stripboard 16 hole by 6 strips – **Figure 2** shows the track cuts on the underside. To the copper side, solder a 12-pin 2-row surface-mount socket; to the front, solder two 12-pin 2-row header pins. **Figure 3** (overleaf) shows this, along with the way in which it is wired up. To save it looking too messy, the two stages of the wiring are shown separately, and a photograph of the finished item is shown in **Figure 4**.
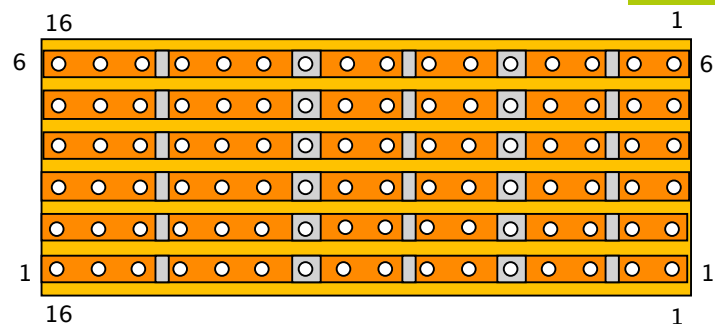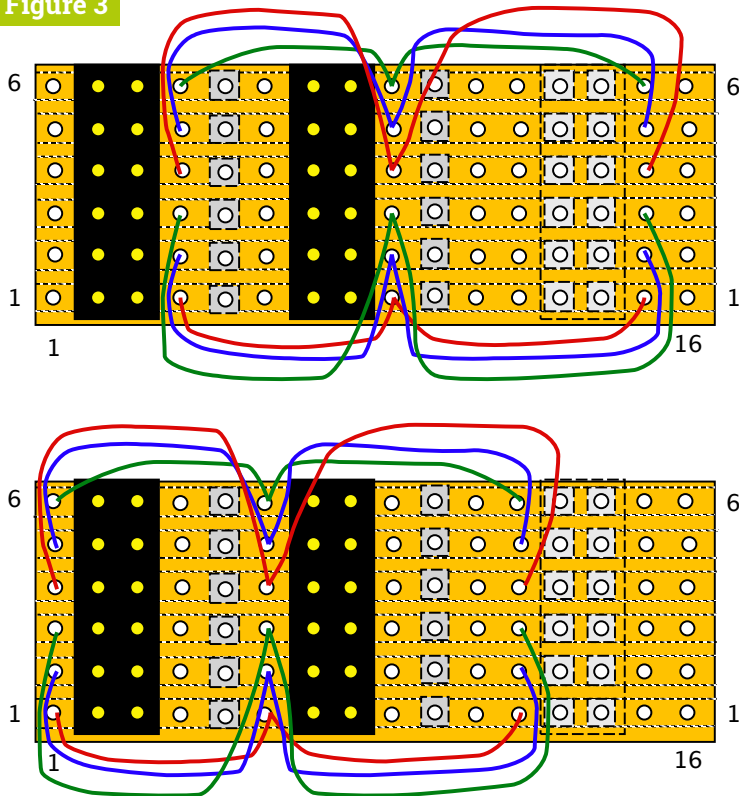
Figure 2
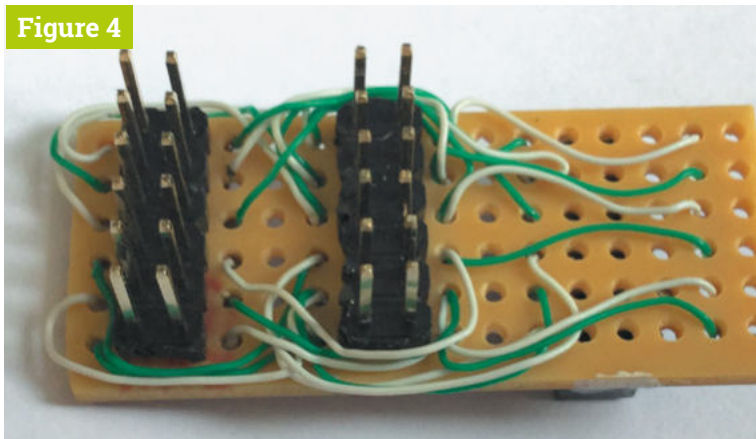

▲ **Figure 2** Copper side of GPIO extender

Figure 3

▲ **Figure 3** Wiring of GPIO extender shown in two stages

▼ **Figure 4** Photograph of GPIO extender

07 **Powering the Arduino**

The link on the top corner of the Pro Micro is left open. This means the board runs at 3V3 (3.3 V) and is only powered when it is plugged into a USB host. To stop the Raspberry Pi damaging the board with a serial signal when the Arduino is unpowered, a 3K3 (3.3 kΩ) series resistor is inserted in Raspberry Pi's TX signal line. On the front panel is a 20-pin 2-row socket to access the peripherals of the Arduino. For clarity, the diagram shows this connector as being split into top and bottom halves, but it is just one socket.

Figure 5

▲ **Figure 5** Wiring of the Arduino board

06 **The Arduino board**

There are two types of Pro Micro Arduino: one with a mini USB connector, and one with a micro USB connector. We prefer the mini connector, as it tends to be more solidly attached to the board. It is slightly wider than the one with the micro connector, but either would fit on the stripboard shown in **Figure 5**. On the reverse, each strip row is broken in the middle to prevent the board from shorting out. The board has straight header pins soldered to it and there is a matching socket soldered to the stripboard.
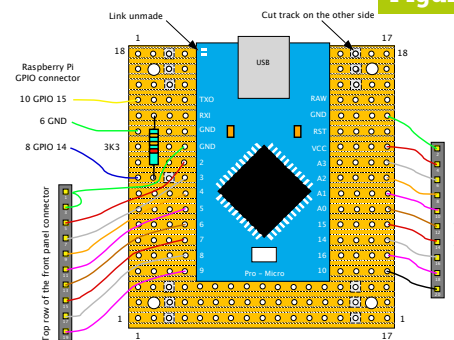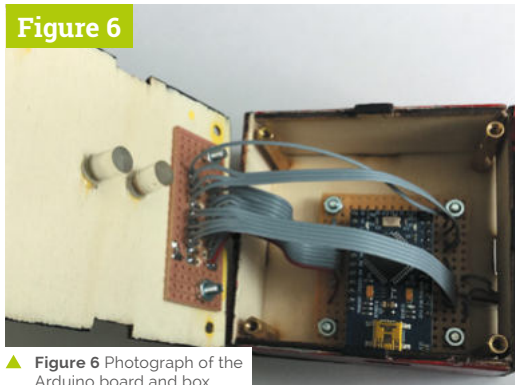
Figure 4

08 **The box**

We made the box using our normal method of 30 mm pillars holding the top and bottom apart, with the sides glued together as a ring. The TX and RX LEDs on the Arduino are useful in seeing if MIDI messages being sent, and received. So that we could see the LEDs blink, we used two 13 mm long, 6 mm diameter, clear acrylic rods glued in the top to act as light pipes. A message is being passed when the LEDs are off. **Figure 6** shows the assembled box. The layout drawing for this box, and more construction photographs, can be found on our GitHub site (**magpi.cc/pibakery**).

09 **Bonus I/O**

As we had an Arduino, with all its peripheral goodies doing nothing, we brought them out to a 20-way socket on the box lid. The pinout of this is shown in **Figure 7**. We have access to 16 different pins and over half of them are dual function. For example, we can use pin 13 of this connector as a PWM-capable digital pin 6, or as analogue input A7. You can only choose one of these two functions to use at any one time. The API for communicating with these peripherals is shown in **Figure 8**.

**Figure 6** Photograph of the Arduino board and box

10 The Arduino software

The Arduino software uses the MIDIUSB library, to present itself as a MIDI HID (human interface device) client device when plugged into a host. This communicates with the host by using four numbers to define a MIDI message; we call this a 'frame'. These frames can be transferred to and from the host by the Arduino and also passed to and from Raspberry Pi. The Python software then uses these frames to deal with messages sent to it, or generate messages to send to the host or communicate with the Arduino peripherals.

> " We have all the Ableton Live sets you need to work along with these examples "

11 Applications

We have written several applications to demonstrate the capability, and workings, of our client interface, both with and without using the Tap-An-LED interface. Many of these look a lot better as a movie, rather than a still. For example, we have four **midi_note_display** programs. These take a stream of MIDI note messages, sent by the host, while playing a MIDI file – and LEDs or Raspberry Pi's screen change accordingly. The colours used are changed according to the velocity of the note. LEDs and the screen can display keyboards, or a unique LED for each note – see **Figure 9** for one example.
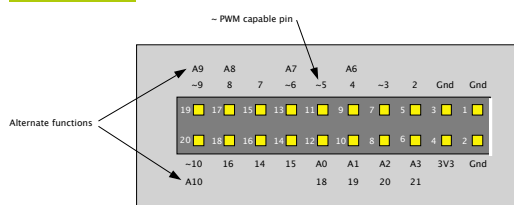
Figure 7 Arduino peripheral connector pinout

frame[0] Header talk to I/O	1	1	1	1	1	0	0	1	
frame[1] Command	C_1	C_0	X	P_4	P_3	P_2	P_1	P_0	P = Pin number

0	0	Digital Read	
0	1	Analogue Read	
1	0	Digital Write	
1	1	Analogue (PWM) Write	

frame[2] Command Digital Write	X	X	X	X	X	X	X	V	V = value to write 0 or 1
frame[2] Command PWM value	A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0	
frame[2] Result Digital Read	0	0	0	0	0	0	0	R	R = Result 0 or 1
frame[3] Result Digital Read	0	0	0	0	0	0	0	0	
frame[2] Result Analogue Read	0	A_9	A_8	A_7	A_6	A_5	A_4	A_3	
frame[3] Result Analogue Read	0	0	0	0	0	A_1	A_0	A_2	
frame[3] Result on Error	1	1	1	1	1	1	1	1	

Figure 8

12 More applications

There is **xy_pad.py**, an example of using the raw data from the touch sensor screen to control two parameters as an X-Y pad in Ableton. In addition, **midi_duet.py** fires random notes, in the key of C, into Ableton for you to play along and improvise against. Then there is **peripheral_request.py** for getting and setting data from the Arduino's peripheral pins. To go along with all this, we have all the Ableton Live sets you need to work along with these examples. Many musical interfaces you can buy come with a licence for a cut-down version of Ableton Live.

13 Other DAWs

There are many more DAWs (digital audio workstations) other than Ableton. There are top-end applications like Apple's Logic Pro X or FL studio, as well as free ones like the Windows-only Cakewalk, or the Apple-only GarageBand. Also, there are budget DAWs; perhaps one of the best of these is Reaper. GarageBand has very good-quality sounds, but the big problem we see with it is that the MIDI works for only one instrument and the implementation of MIDI controls is limited. There are many more DAWs if you search for 'Free DAW'. **M**

◀ **Figure 8** How the software accesses the Arduino peripherals

Top Tip 👍

Labelling

We used a Dymo LetterTag label printer on clear plastic strip to make the labels for the box.

▼ **Figure 9** Five keyboards showing MIDI note messages being sent on different channels
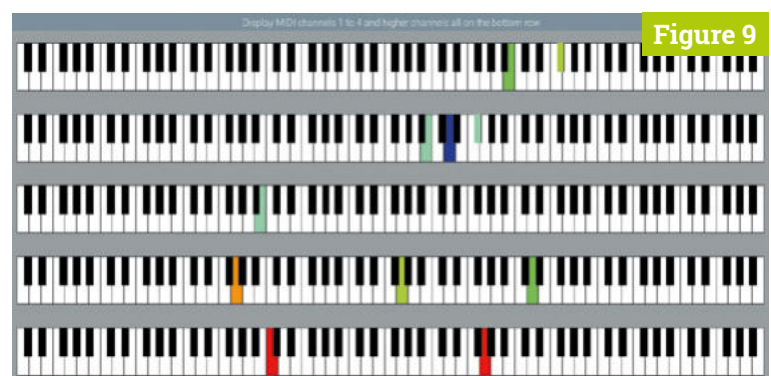
Figure 9

> **Players must change the colour of every cube to complete the level.**

> **The cabinet employed a diagonal joystick to move Q*bert around.**
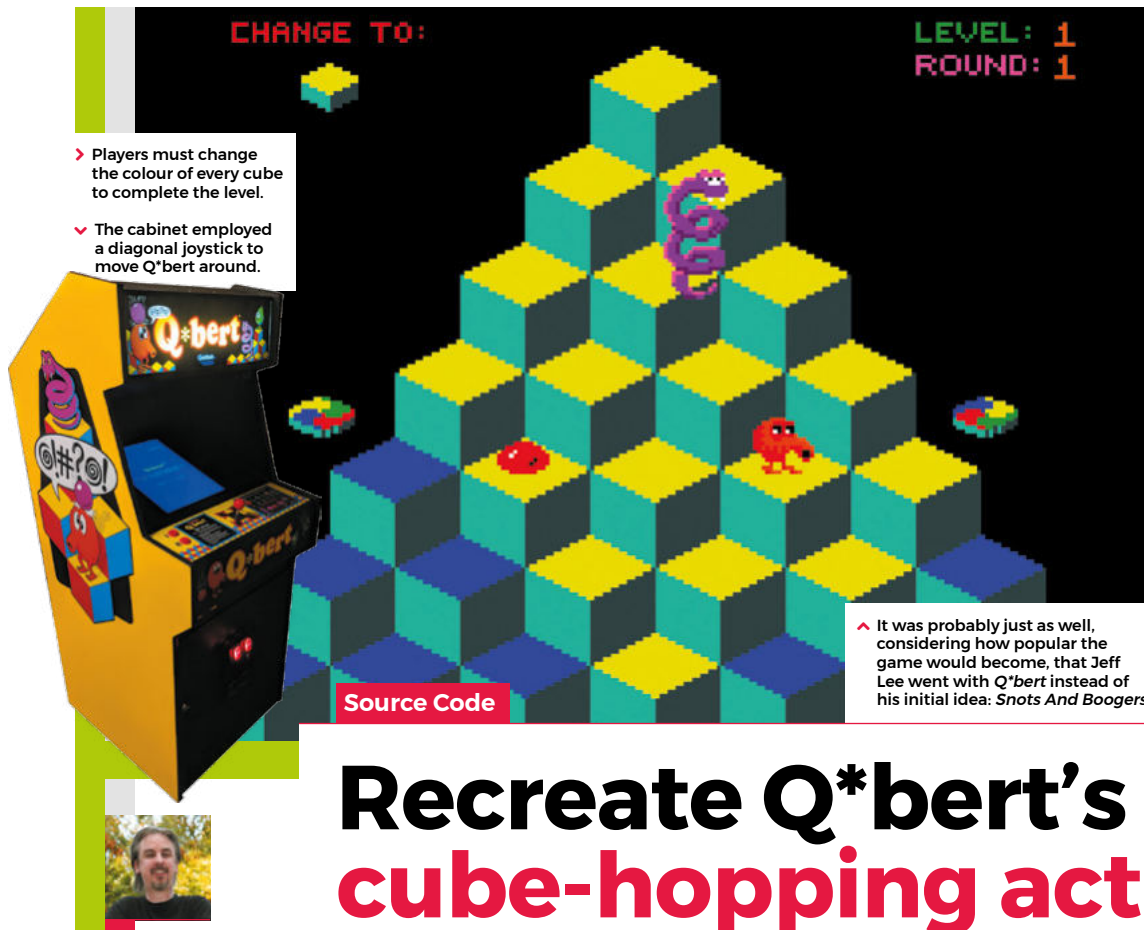
Source Code

∧ It was probably just as well, considering how popular the game would become, that Jeff Lee went with *Q*bert* instead of his initial idea: *Snots And Boogers*.

Wireframe

This tutorial first appeared in Wireframe, our sister magazine that lifts the lid on the world of video games. Every issue includes tutorials and in-depth interviews, along with news and reviews of the latest indie and triple-A games.

To find out more, visit their website at **wfmag.cc**.

Check out their subscription offers at **wfmag.cc/subscribe**.

Recreate Q*bert's cube-hopping action

Code the mechanics of an eighties arcade hit

AUTHOR
MARK VANSTONE

ate in 1982, a funny little orange character with a big nose landed in arcades. The titular Q*bert's task was to jump around a network of cubes arranged in a pyramid formation, changing the colours of each as they went. Once the cubes were all the same colour, it was on to the next level; to make things more interesting, there were enemies like Coily the snake, and objects which helped Q*bert: some froze enemies in their tracks, while floating discs provided a lift back to the top of the stage.

*Q*bert* was designed by Warren Davis and Jeff Lee at the American company Gottlieb, and soon became such a smash hit that, the following year, it was already being ported to most of the home computer platforms available at the time. New versions and remakes continued to appear for years afterwards, with a mobile phone version appearing in 2003. *Q*bert* was by far Gottlieb's most popular game, and after several changes in company ownership,

the firm is now part of Sony's catalogue – *Q*bert*'s main character even made its way into the 2015 film, *Pixels*.

*Q*bert* uses isometric-style graphics to draw a pseudo-3D display – something we can easily replicate in Pygame Zero by using a single cube graphic with which we make a pyramid of Actor objects. Starting with seven cubes on the bottom row, we can create a simple double loop to create the pile of cubes. Our Q*bert character will be another Actor object which we'll position at the top of the pile to start. The game screen can then be displayed in the `draw()` function by looping through our 28 cube Actors and then drawing Q*bert.

We need to detect player input, and for this we use the built-in keyboard object and check the cursor keys in our `update()` function. We need to make Q*bert move from cube to cube so we can move the Actor 32 pixels on the x-axis and 48 pixels on the y-axis. If we do this in steps of 2 for x and 3 for y, we will have Q*bert on the next cube in 16 steps. We can also change his image

to point in the right direction depending on the key pressed in our `jump()` function. If we use this linear movement in our `move()` function, we'll see the Actor go in a straight line to the next block. To add a bit of bounce to Q*bert's movement, we add or subtract (depending on the direction) the values in the `bounce[]` list. This will make a bit more of a curved movement to the animation.

Now that we have our long-nosed friend jumping around, we need to check where he's landing. We can loop through the cube positions and check whether Q*bert is over each one. If he is, then we change the image of the cube to one with a yellow top. If we don't detect a cube under Q*bert, then the critter's jumped off the pyramid, and the game's over. We can then do a quick loop through all the cube Actors, and if they've all been changed, then the player has completed the level. So those are the basic mechanics of jumping around on a pyramid of cubes. We just need some snakes and other baddies to annoy Q*bert – but we'll leave those for you to add. Good luck! ⓦ

Bouncing between cubes in Python

Here's Mark's code for a *Q*bert*-style, cube-hopping platform game. To get it running on your system, you'll need to install Pygame Zero – full instructions are available at **wfmag.cc/pgzero**.

Download the code from GitHub: **wfmag.cc/wfmag42**

```python
# Q*bert

WIDTH = HEIGHT = 500

gameState = 0
blocks = []
qbert = Actor('qbert2', center=(250, 80))
qbert.movex = qbert.movey = qbert.frame = count = 0;
bounce = [-6,-4,-2,-1,0,0,0,0,0,0,0,1,2,4,6]

for r in range(0, 7):
    for b in range(0, 7-r):
        blocks.append(Actor('block0', center=(60+(b*64)+(r*32),
400-(r*48))))

def draw():
    screen.blit("background", (0, 0))
    for b in range(0, 28): blocks[b].draw()
    if gameState == 0 or (gameState == 1 and count%4 == 0):
qbert.draw()
    if gameState == 2 : screen.draw.text("YOU CLEARED THE
LEVEL!", center = (250, 250), owidth=0.5, ocolor=(255,255,255),
color=(255,0,255) , fontsize=40)

def update():
    global gameState, count
    if gameState == 0:
        if qbert.movex == 0 and qbert.movey == 0 :
            if keyboard.left: jump(32,48,3)
            if keyboard.right: jump(-32,-48,1)
            if keyboard.up: jump(-32,48,0)
            if keyboard.down: jump(32,-48,2)
        if qbert.movex != 0 : move()
    count += 1;

def move():
    if qbert.movex > 0 :
        qbert.x -=2
        qbert.movex -=2
    if qbert.movex < 0 :
        qbert.x +=2
        qbert.movex +=2
    if qbert.movey > 0 :
        qbert.y -=3 - bounce[qbert.frame]
        qbert.movey -=3
    if qbert.movey < 0 :
        qbert.y +=3 + bounce[qbert.frame]
        qbert.movey +=3
    qbert.frame +=1
    if qbert.movex == 0 :
        checkBlock()
```

```python
def checkBlock():
    global gameState
    block = -1
    curBlock = 0
    numSelected = 0
    for r in range(0, 7):
        for b in range(0, 7-r):
            x = 60+(b*64)+(r*32) -2
            y = 400-(r*48) -32
            if qbert.x == x and qbert.y == y :
                block = curBlock
                blocks[block].image = "block1"
            curBlock +=1
    if block == -1 : gameState = 1
    for b in range(0, 28):
        if blocks[b].image == "block1" : numSelected += 1
    if numSelected == 28 : gameState = 2

def jump(x,y,d):
    qbert.movex = x
    qbert.movey = y
    qbert.image = "qbert"+str(d)
    qbert.frame = 0
```


Our homage to Gottlieb's classic *Q*bert* game. Try not to fall into the terrifying void.

Holiday Projects
for a Festive Home

Deck your halls with Raspberry Pi decorations and more this Christmas

The holiday season is upon us and we fancy going all out this year to turn our homes into winter wonderlands. With Raspberry Pi you can create incredible decorations with automation, lights, sound, remote control, and pretty much anything else you can think of!

We've put together a selection of fantastic community projects to give you some inspiration for decorating your house inside and out. Let's get festive.

Outdoor decorations

Light up your street with pure seasonal cheer (and some LEDs)

Your house could look like this, with careful use of a ladder

Xmas lights for beginners

Sometimes you need to do something a little grand, especially for the holidays, and lighting up the outside of your house is one excellent way to do it. If you're not sure where to begin with this, then this guide by Makin'Things will not only get you set up with lights, but also shows how to get them to sync up with music.

It uses the excellent lightshowpi Python library (**lightshowpi.org**) to make the music syncing fairly easy. It also uses relays and a lot of power, so be extra careful if you plan to follow it!

magpi.cc/xmaslightsbeginners

LED display matrix

If you don't fancy doing the whole house, then maybe a window will do! Andrew Oakley shows you through how to create a set of animated LEDs for not too much money. It also takes PNG images, so you don't need to program each individual LED and it can even scroll text as well!

While relatively simple and cheap, you may have to do some woodwork, so get it started ahead of time and make sure to be careful when using any carpentry tools.

magpi.cc/ledmatrix

▲ The matrix is fully programmable to show images and scrolling text

▲ You may have your work cut out to get it ready

2018 Christmas Light Show

Are you really doing your outside lights correctly if you're not worrying your neighbours? If you really want to see how much you can do with lightshowpi and the kind of setup Makin'Things does, this light show which includes lawn ornaments, a tree, and 4000 lights should give you some inspiration.

It's all still controlled by music as well. Once again, you'll need to be extremely careful with heights and electricity use if you plan to recreate this.

magpi.cc/2018lightshow

▲ You might want to warn your power provider before switching these on

▲ Different colours and arrangements can be achieved

Power up your tree

Even with just a fake Christmas tree, you can really bring it to life with a Raspberry Pi

Smart Christmas tree lights

Not only are these Christmas lights made with fully programmable NeoPixels, giving you unlimited flexibility in colours and patterns, but they also add voice control so you don't even need to touch them! Sure, you could implement some remote SSH system, but this way is a bit more fun.

We made this in *The MagPi* last year and we think it still holds up! You may want to invest in a little 5V power supply adapter, as changing out batteries all the time does get a little boring.

magpi.cc/smartxmaslights

▲ You can use a bigger tree if you have enough NeoPixels

Star kit

Don't fancy printing out and rigging up your own customised tree star? The Pi Hut has you covered with this excellent star kit that just requires you to add a Raspberry Pi Zero and a bit of code – which you can hack and change yourself of course!
Find it here: **magpi.cc/tphstar**

▲ Always test your circuits

Tree Star

Another *The MagPi* original, this one uses a 3D-printed star to act as a tree topper, with some LEDs installed inside to light it up! It's been a few years since we selected this specific 3D star file from Thingiverse, so you might be able to find something better or whip one up yourself.

Make sure to scale the star for your tree, though – behind the scenes, this star wouldn't stay on the original tree we had and we needed a bigger one! If you're doing the smart tree lights as well, you can easily combine the two.

magpi.cc/xmasornament

▲ If you can find a translucent printing material, that will work best

▲ With the right 3D-printed parts, this can look very natural

YouTube Christmas Ornament

▲ It doesn't require many parts either

We all know someone who needs to see the Coca-Cola Christmas advert before Christmas starts for them. You may even be that person! Relive all your favourite Christmas adverts through this ingenious build that puts a tiny display on your tree to play them all.

You have to supply the videos yourself, though, so if you really want to embarrass someone, you'll need to digitise some old VHS tapes of Christmas past and upload them. Or just put your favourite Christmas films on there.

DIY ornaments

Make your own Raspberry Pi-themed ornaments!

You can find many kinds of ornaments you can 3D-print on Thingiverse, and you can always make yourself one if you're handy with Blender. Raspberry Pi's own Alex Bate created these Raspberry Pi logo and Code Club logo baubles a few years back which you can print yourself! Have a look at them – and find the links to the files – here: **magpi.cc/festivebaubles**

Deck the halls

Give the rest of your home a bit of seasonal magic

▼ The façade is pretty fun, although you could probably add fake logs if you really wanted

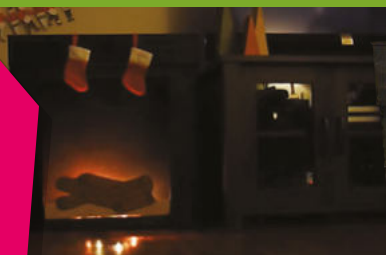▲ It's just like having a real fireplace, albeit without Dick Van Dyke cleaning it

pireplace

We must admit, we don't *quite* get the appeal of the fake fire on the TV during Christmas. This we can get behind, though – creating a fake fireplace and adding NeoPixels to create a warming fire effect that is sure to cozy up any room.
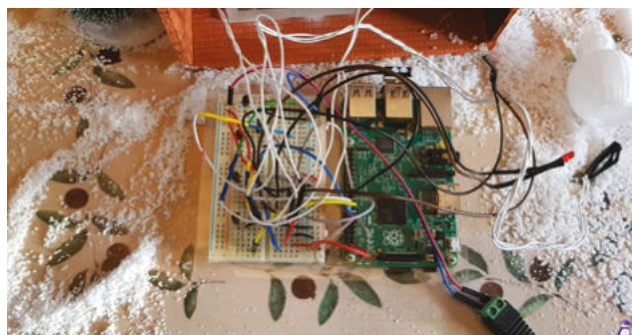
It's even got a web interface you can control from your phone, allowing you to change the colours and turn it on and off. Very handy, and maybe a little spooky if you time it right to catch folks in the act of present-feeling.

magpi.cc/pireplace

▼ All the electronics are stored inside the house. Be careful using the 5V terminal!

Christmas house and snowman

This little diorama was created by Stewart Watkiss (aka PenguinTutor) to be part of an outdoor railway. However, it also functions as an indoor decoration. A string of LEDs on the front of the building act as some nice Christmas lights, and a snowman has NeoPixels inside so it can glow with awesome Christmas power.

The house and snowman were 3D-printed, although you could probably find some model kits that will allow you to do similar. We like the snow effect on the tray, and the little tree and people to give it the correct sense of scale.

magpi.cc/xmashouse

▼ The light display is really very nice, with alternating colours on a slow cycle

Smart gingerbread house

Gingerbread houses are a classic Christmas ornament for some families – one that probably wouldn't last to Christmas Day intact in our house. Estefannie decided to take it about two steps further, as she's wont to do, and fully automated a smart gingerbread house. It's also covered in enough sweets to attract Hansel and Gretel.

The whole thing also has a remote control function so you can switch the lights on and off, open and close the door, and a lot, lot more.

magpi.cc/gingerbread
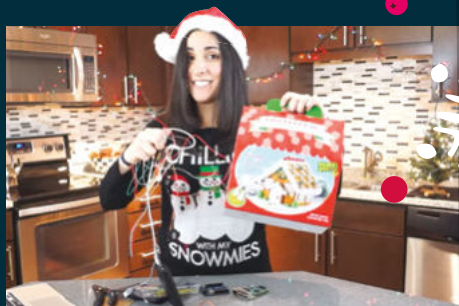
▲ Just some of the parts you'll need for this build

▲ The door opens and closes, which is pretty excellent

Decoration kits

Grab these fun little kits for more decorations!

SNOWPI RGB
snowpi.xyz
price: £9

CHRISTMAS TREE SOLDER KIT
magpi.cc/treekit
price: £6

3D XMAS TREE
magpi.cc/3dxmastree
price: £15

Sense HAT advent calendar

▼ The version you'll make will let you know what day it is when you 'open' the door

Too impatient to wait until Christmas Day for your presents? Then how about a slow drip-feed of daily gifts like you'd get in an advent calendar? This digital version doesn't give you chocolates, unfortunately, but it is a neat and simple little project to help you get into the festive mood.

It's from the Raspberry Pi Projects website, so it's nice and easy to set up and requires very few components as well, relying more on code than anything else.

magpi.cc/senseadvent

Happy holidays

from all of us at *The MagPi*!

Stellina

Go stargazing with this Raspberry Pi-powered, automated telescope.
Rob Zwetsloot explores the universe with it

SPECS

CPU:
Raspberry Pi 3

APERTURE:
80 mm

FOCAL LENGTH:
400 mm

FOCAL RATIO:
F/5

FEATURES:
Automated tracking and focus

Raspberry Pi has many links with space. From high-altitude balloons carrying teddy bears and stellar photography with Camera Modules, to Raspberry Pi computers on the International Space Station running kids' code. This is the first time that we've seen a product that uses a Raspberry Pi for a tracking telescope – or more accurately, an observation station.

See, Stellina isn't just for getting a better look at the moon or maybe seeing a planet: it's designed to look into the deep reaches of space and bring you images of nebulas and galaxies that you could never see with the naked eye. And it's all controlled from a smartphone or tablet, which is pretty clever.

Space in your hands
Probably the most unique feature of Stellina is how it's not only fully controlled from your phone or tablet, but also you get to see what it's pointing at from your device. No need to peer through a viewfinder if that isn't your thing, although if it is your thing you may want to look somewhere else. A Raspberry Pi 3 inside creates a local wireless network that works with a Stellina app for remote viewing and controlling.

Because of this control, pointing at an object is incredibly simple: there's a predetermined list of cosmic destinations you can select from in the app, and Stellina automatically swivels and raises its lens towards it before continuing to track it throughout the night, if you so wish. The longer

> ❝ A Raspberry Pi 3 inside creates a local wireless network that works with a Stellina app for remote viewing and controlling ❞

you look at these objects, the better picture you'll get as the software 'stacks' the photos on top of each other to get a clearer image. You can then do some colour correcting of the image when saving it, or even just invert the colours for that very scientific black-on-white look.

We took a Stellina out to a field in the middle of nowhere one evening to give it a proper test, and we were pleasantly surprised by the results. Despite having the various planets in our solar system selectable to observe, the real magic occurs when you get it to look at nebula and galaxies. As you might expect, the darker it is the better, and some patience is required if you want to get some truly astonishing sights. Saturn was the first and last target of the evening, with barely a blurry smudge
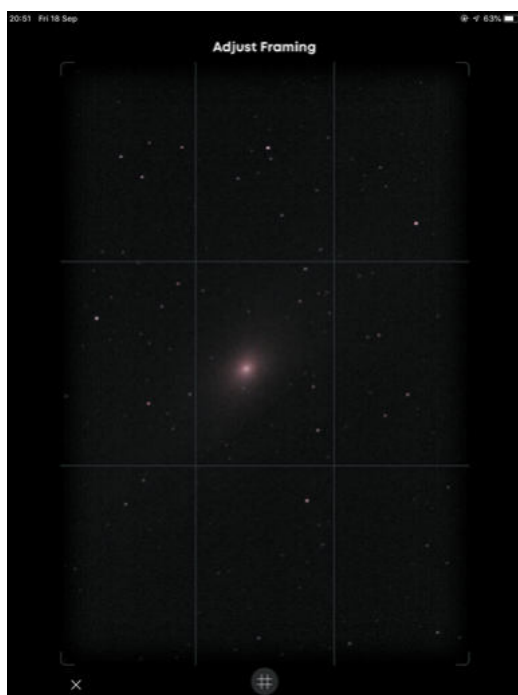
▼ Its modern chic look hides its function. The plastic casing isn't quite as premium as we'd expected, though
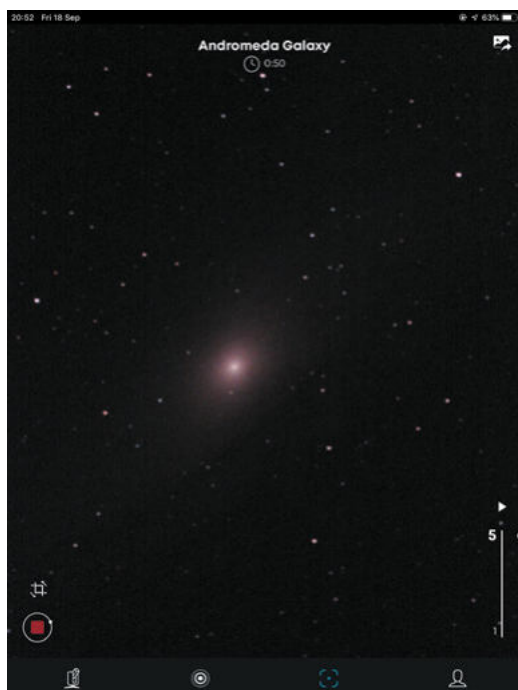
It's recommended to spend 50 minutes observing our galactic neighbour, but you'll still get an interesting image to start

Adjusting the tracking can help you look at celestal objects for longer, or with a better use of rule of threes!

visible just after dusk, and the rings clearly circling it several hours later. Which was quite breathtaking, even if the whirring of the motors as it tracked the planet across the sky was a touch distracting.

Balcony view

We feel that this device is more aimed at folks with a balcony who'd rather be sitting inside while looking at Jupiter or Andromeda – it does claim to filter out light pollution after all. The kind of people who might have a nice balcony to put it on may also be a bit more comfortable with the hefty price tag, which runs quite a lot higher than more traditional telescope/automated tripod systems.

The magic here is in the software and ease of use then, although you will be paying a premium for it – however, a much cheaper version is in the works, and we're interested to see how it compares. M

Verdict

While the price is eye-watering, if you really like looking at stuff in space and don't get out of the city much, you could have a magical time with it.

9 /10

Lyra Handheld
Game Console

SPECS

CPU:
1.4GHz 64-bit quad-core ARM Cortex-A53 via Raspberry Pi CM3L

MEMORY:
1GB LPDDR2 SDRAM via Raspberry Pi CM3L

BATTERY:
3000 mAh LiPo

DISPLAY:
5" TFT LCD 800×480 resolution

AUDIO:
Integrated speaker, 3.5 mm audio output, and HDMI

Fantastic-looking Raspberry Pi Compute Module 3 Lite-powered handheld game console for gaming on the go. By **Wesley Archer**

Even with the plethora of kits available today, playing your favourite retro games on the go with a Raspberry Pi typically involves a do-it-yourself approach. Often this involves a 3D-printed case and a lot of trial and error with small and fiddly components.

The Lyra Handheld Game Console is attempting to change that. After a successful launch in July 2019, Kickstarter veteran Creoqode set out to make a handheld gaming system that looked the part, was easy to assemble, and was more powerful than

▲ Small yet powerful. The supplied Raspberry Pi Compute Module 3 Lite provides plenty of processing power

❝ We had our Lyra assembled in under 15 minutes ❞

any other Raspberry Pi-powered handheld game console on the market at the time. The result is Lyra, a handheld game console that is available in kit form (or fully assembled if you fear nuts and bolts), and utilises the power of Raspberry Pi Computer Module 3 Lite.

Unlike many other Raspberry Pi-based handheld game consoles available today, the Lyra resembles the form factor of a Sony PSP and Nintendo's Game Boy Advance, which makes a nice change to the tried-and-tested Game Boy-style systems, along with the bonus of a larger, widescreen display.

Easy assembly

When the Lyra arrived, we were impressed with the packaging, which can double up as a protective case when your Lyra is not in use, and the quality of the parts in the kit – we loved having the option of clear or black buttons to choose from. As we are partial to a bit of tinkering, we opted for the kit version, so we had to assemble our Lyra ourselves. Whilst there were no physical instructions provided, the online tutorial is packed with detailed photos and step-by-step instructions, and we had our Lyra assembled in under 15 minutes. The fiddliest part was attaching the screen when closing the case! For convenience, Creoqode has created a custom-built image that

▶ The Lyra looks fantastic and fits great in the hands. An ideal choice for gaming on-the-go

▲ The packaging is well-designed and sturdy, and it makes a great storage case when your Lyra is not in use

utilises RetroPie, so once this was downloaded and flashed to our microSD card, we were up and running in no time. It's a shame that a manual install guide was not available for those who prefer setting up RetroPie to work on the Lyra themselves, especially as pre-built SD card images can quickly become outdated.

Small but mighty

One thing we liked about the Lyra was the inclusion of the Raspberry Pi Compute Module 3 Lite (CM3L). Whilst pricier than a Raspberry Pi Zero, the CM3L brings the power and small footprint that is perfect for a handheld game console. The CM3L clips into Creoqode's custom-made circuit board and whilst the lack of WiFi is a shame, the micro USB port allows you to connect your own USB devices (with the help of an adapter) for internet connectivity. The addition of an HDMI port allows you to connect your Lyra directly to a large display / TV, which is great for gaming at home too.

▲ The kit version is fairly easy to assemble using the online tutorial

We did notice that the case didn't quite close perfectly, so small gaps were visible by the micro USB charging and headphone ports, and the lack of a screen protector was a shame, but the performance of the Lyra is second to none in a competitive market for handheld gaming. **M**

Verdict

The Lyra is a great product in a competitive market. Assembly was straightforward and the power the CM3L brings is fab. The case could be better, but for gaming on the go, it is ideal.

8/10

pi-top [4] **DIY Edition**

▶ pi-top ▶ **magpi.cc/pitop4diy** ▶ £95 / $100

Sturdy and feature-packed case for Raspberry Pi. **Lucy Hattersley** asks if pi-top [4] is the right portable option

The pi-top [4] DIY Edition is a sturdy, well-built, and nicely designed plastic and rubberised black case with a green underside (as a nod to previous pi-top bright green laptops). Previously sold as an educational tool, with a Raspberry Pi 4 inside and a Foundation kit of electronics, it's now sold separately in this DIY edition.

It has considerable heft to withstand the rigours of the classroom. We measured the base unit at 100×130×35 mm, and weighed it in at 397 g.

The GPIO sockets (with BCM numbering) break out to the top of the case alongside a small 120×64 OLED display and four control buttons, a built-in battery, and a speaker.

You gain a second USB-C port for the upcoming pi-top Bluetooth Keyboard and FHD Touch Display, which promises to transform pi-top [4] into a touchscreen laptop (**magpi.cc/ptdisplay**).

Battery and screen

It's the only case we've seen that contains a built-in battery and display. Making pi-top [4] good for mobile use and also acts as power redundancy. It takes around an hour to charge and lasts for around five hours of use.

The small 128×64 OLED displays information on the battery level, CPU load, and network connection. We were glad to discover an OLED and Button API in the documentation. The 'ptoled' module enables you to draw text, images and GIFs to the display, and plot and draw shapes.

Built-in cooling

pi-top [4] includes a fan that automatically adjusts its speed according to the CPU temperature. We tested it with Stressberry (**magpi.cc/stressberry**)
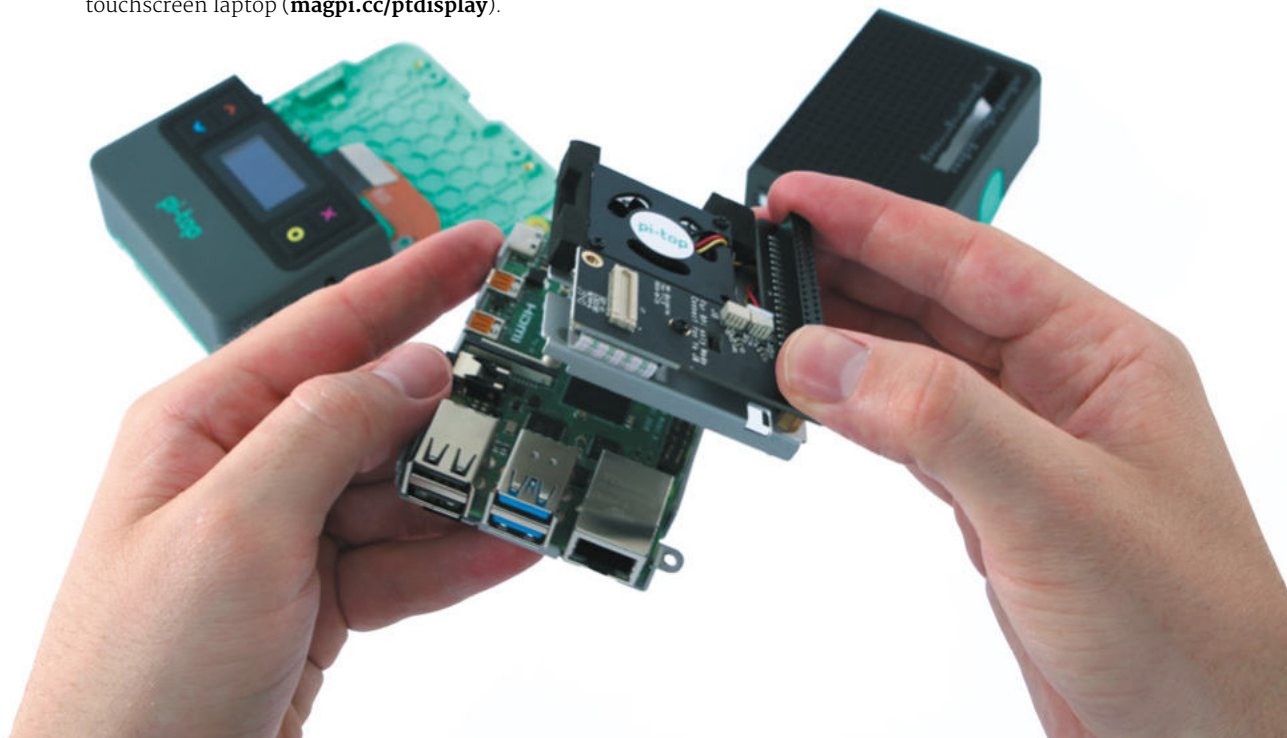
▶ Add your own Raspberry Pi 4 to the pi-top [4] DIY Edition

and found that pi-top [4] idled at 35°C, maxing out under stress at 45°C (with an ambient temperature of 14°C).

We overclocked it and ran pi-top [4] at 2GHz, and the temperature maxed out at 56°C. At all times the fan remained at a constant low non-intrusive spin, with speed controlled by the pi-top Hub. Reconnecting the fan to a second jumper enables manual control (**magpi.cc/ptfan**).

> ❝ A range of unique features make a compelling case for the additional cost ❞

Installation

Installing Raspberry Pi inside pi-top [4] took around five minutes. Wil Bennett, pi-top's director of technology, has a YouTube video that walks you through the installation process: **magpi.cc/ptinstallation**.

pi-topOS Solaris is a feature-packed operating system built on top of Raspberry Pi OS (32-bit) 'Buster'. It's possible to use Raspberry Pi OS and control the pi-top hardware. We used this script:

```
echo "deb http://apt.pi-top.com/pi-top-os
sirius main contrib non-free"  | sudo tee
/etc/apt/sources.list.d/pi-top.list &>
/dev/null

curl https://apt.pi-top.com/pt-apt.asc | sudo
apt-key add

sudo apt update

sudo apt install --no-install-recommends -y
pt-device-manager pt-sys-oled pt-firmware-
updater

sudo reboot
```

On the whole, we really like pi-top [4]. The price remains a hurdle, however, it has a range of unique features that make a compelling case and there's no arguing with the build quality. **M**

Verdict

pi-top [4] is very easy to like once you get over the price, and we enjoyed playing with the OLED display. If you don't intend to use the Foundation kit or make use of the battery for portable computing, there are cheaper options.

9 /10

10 Amazing:

Life-improving projects

Make your day-to-day nicer, thanks to these Raspberry Pi projects

Raspberry Pi is small yet powerful, making it perfect for sneaking into and behind places in your own home, powering up anything you deem fit. Here are ten ways you can use a Raspberry Pi to make your home and life a little bit better. M

⚠ Warning! Mains Electricity

Some of these projects use mains electricity with a voltage relay. Be careful when working with mains electricity.
magpi.cc/ electricalsafety

▲ Smart doorbell and video intercom

Somebody's at the door

A lot of video doorbells are one-way – you can see your guest, but they can't see you. This version allows you to have a face-to-face conversation if you so wish. Much more formal.

magpi.cc/smartdoorbell

▲ Touchscreen thermostat

Automated heating

Make your heating smart with the help from a Raspberry Pi in this detailed thermostat hack. The concept is to take the Nest concept and make it even better. Be careful with the use of electricity and relays in this project – make sure it's grounded and insulated.

magpi.cc/thermostat

▶ Alexa coffee maker

Voice-controlled lattes

If tea isn't your thing, then maybe this automated coffee maker will be? It's a simple robot for the moment, controlling on/off function so it's not choosing grind size and brewing time. Still, it does have a flappy mouth.

magpi.cc/alexacoffee
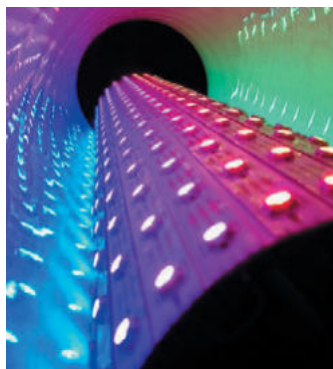
◀ Circadia sunrise lamp

Wake at 'dawn'

Some folks like to rise with the sun. The only problem is, you can't set the sun like an alarm clock. Especially great in the winter if you have to get up before the sun rises.

magpi.cc/sunrise

▲ Hamster feeder

Automated feeding

The creator doesn't own any hamsters, but if he did, they'd be well fed at appropriate times. This can be adapted for any pet really, as long as you scale it up for bigger ones.

magpi.cc/hamsterfeed

Kodi

TV improved

Power up your TV with Kodi – which we like to add to Raspberry Pi via LibreELEC (**libreelec.tv**). You can stream video and music across your network, and there are great metadata scrapers installed as well.

kodi.tv

▲ Ultimate home door lock

3FA entry

Want to secure a door as safely as possible? This method includes an NFC fob, a PIN code, and a one-time passcode sent via SMS. Good for making the biscuits slightly harder to snack on. This project uses relays again, so be careful and follow safety guidelines.

magpi.cc/smartlock
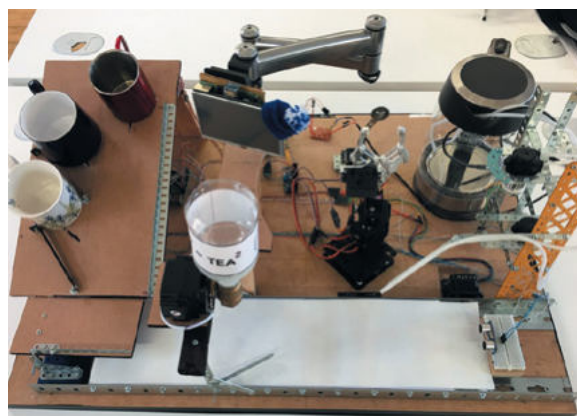
▲ AI Teasmade

Tea on demand

Much more involved than your classic Teasmade – this one is more like a Rube Goldberg contraption. Makes a good cuppa, though.

magpi.cc/teasmade

▲ MagicMirror

Everything at a glance

Check yourself out while also checking out what your day looks like. A classic Raspberry Pi project, and one that is genuinely very useful. Especially if you're in a T-shirt while it's 4°C.

magicmirror.builders

▶ Furlexa voice assistant

'Cute' smart speaker

While you may not wish to use a Furby for this project, the rest of the hardware and software is great! Maybe you could install it into an Aibo robot dog instead?

magpi.cc/furlexa

Learn Sense HAT
with Raspberry Pi

The best resources to use with this versatile Raspberry Pi add-on board. By **Phil King**

Astro Pi resources

The Sense HAT is an official add-on board that adds a range of motion sensors to Raspberry Pi, including a gyroscope, accelerometer, and magnetometer, along with temperature, pressure, and humidity sensors. It also features an 8×8 LED matrix and five-button joystick.

This versatile board was designed especially for a space mission. Two Astro Pi units – comprising a Raspberry Pi with Sense HAT in a special case – are currently aboard the International Space Station (ISS). Astro Pi is an ESA (European Space Agency)
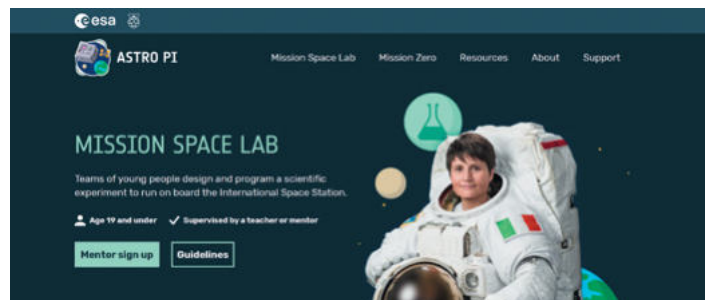
project run with the Raspberry Pi Foundation. It enables young people to conduct scientific investigations in space by writing computer programs that run on the Astro Pi devices aboard the ISS. Students up to 19 years old can take part in the

Mission Space Lab, while those 14 and under can get involved in the simpler Mission Zero.

Even if you don't want to take part, Astro Pi has a solid set of resources designed to help students set up the Sense HAT and collect data from it.

Magazine tutorials

Sense HAT projects from *The MagPi*

SENSE HAT EMULATOR

Don't have a Sense HAT? You can still enjoy creating projects using the Sense HAT Emulator built into Raspberry Pi OS. This tutorial shows you how to use it.
magpi.cc/59

MATHEMATICA AND THE SENSE HAT

From the same issue, this tutorial shows you how to collect and display environmental data using the Sense HAT and Wolfram's language function.
magpi.cc/59

READING SENSE HAT DATA WITH RUST

Want to learn a new programming language that's ergonomic and safe, yet runs really fast? Dive in to Rust and read data from your Sense HAT.
magpi.cc/73

Experiment with the Sense HAT

CREATOR

The Pi Education Team

Price:
Free download

magpi.cc/ sensehatbook

While no longer available in printed form, this compact book from *The MagPi Essentials* range can still be downloaded as a free PDF. An extensive feature on the Astro Pi mission details how the units were designed and then launched into space to reach their new home on the International Space Station – to be joined by British ESA astronaut Tim Peake soon after. To help you begin, there are guides to getting started with physical computing using both Python and Scratch – the Raspberry Pi version of Scratch features special extension blocks for controlling electronics (as well as the Sense HAT board).

The book then launches into some step-by-step tutorials to help you get started with your Sense HAT, demonstrating how to display images on the LED matrix and how to read the various sensors on board, including the gyroscope, accelerometer, and magnetometer. Fun projects to code include a Gravity Simulator, Digital Magic 8 Ball, Interactive Pixel Pet, Astronaut Reaction Times Game, and Data Logger.
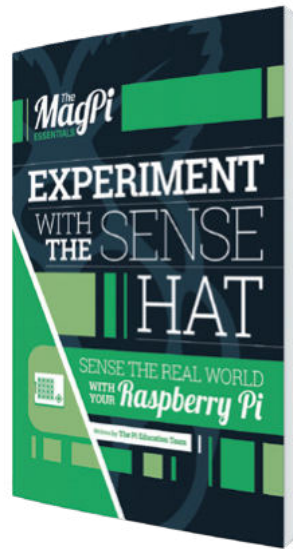
Raspberry Pi Projects

CREATOR

Pi My Life Up

Price:
Free

pimylifeup.com

The Raspberry Pi Foundation's learning resources website features several tutorials to help you get started with your Sense HAT and make some fun projects with it using Scratch or Python. Even if you don't own a Sense HAT yet, you can experiment with writing Python programs in an online emulator to see the effects.

Start with a simple Countdown Timer on the board's LED matrix, before moving on to games such as Flappy Astronaut, Marble Maze, Tightrope, and Pong.

More complex projects include an MP3 Music Player and Weather Logger. There's even a tutorial to explore SpaceCRAFT – a winning Astro Pi competition project – in which you can visualise data from the Sense HAT's sensors in the Minecraft world. M

Web resources

Get the most from your Sense HAT with this online documentation

SENSE HAT API
This handy online reference guide outlines all the functions used to control the Sense HAT (and used in a variety of different tutorials) from your Python programs.
magpi.cc/sensehatapi

SENSE HAT GITHUB
If you want to look a bit deeper under the hood of the Sense HAT API for Python, visit the GitHub repo, which also contains some example programs.
magpi.cc/sensehatgit

SENSE HAT DOCUMENTATION
Check out the official documentation for the Sense HAT, which includes info on calibration. There's also a link to the hardware schematics.
magpi.cc/sensehatdoc

Christina Foust

One of the creators of the current Digital Making at Home streams tells us how she went from teacher to a different kind of teacher

> Name **Christina Foust** | > Occupation **Club Program manager**
> Community role **Community support** | > Twitter **@Foustberrypi**

▼ The weekly streams have been running for months now, and you can catch them every Wednesday!

L ast month we talked to Mister C about the Raspberry Pi Foundation's new series of Digital Making streams. This month we talk to his most excellent US counterpart, Christina Foust from Raspberry Pi Foundation North America. While she's always been a part of the streams, more recent ones have been taking place much later in the day UK time, so that they're more accessible to American students.

"We're having a lot of fun!" Christina tells us. "It's honestly the highlight of my week, and we're getting a positive

response from the community. It's really been nice to connect with professionals and youth creators and share their experiences with the community. I'm excited to see where the live stream adventure takes us!"

How did you first learn about Raspberry Pi and related programmes?
Honestly, I learned about Raspberry Pi when I found the job listing in November 2017. I was in a temporary admin role supporting a school while the principal was on parental leave, and I needed a job! I knew about

Arduino because my dad made projects, and I knew about coding and Scratch because I was a teacher, but I had never heard of Raspberry Pi before. Even during the interview process, the focus was on our clubs' programmes in the USA. Then when I got the job (YAY!) and was meeting all the teams, I truly started to grasp the global reach of both the hardware and our education programs.

To be honest, I had friends who were familiar with Raspberry Pi and were confused by why/how Raspberry Pi had hired me, a former teacher and not an experienced hardware or software engineer. I also had friends who thought I made a career change and was working at a bakery. I share the above because I want folks who are reading this to know that they can and should apply to jobs that interest them. I got this job because I am an educator, I love kids, and I'm good at community engagement. If I had listened to one group of friends, I might have felt I wasn't qualified to work at RPF or if I listened to another group, I might have
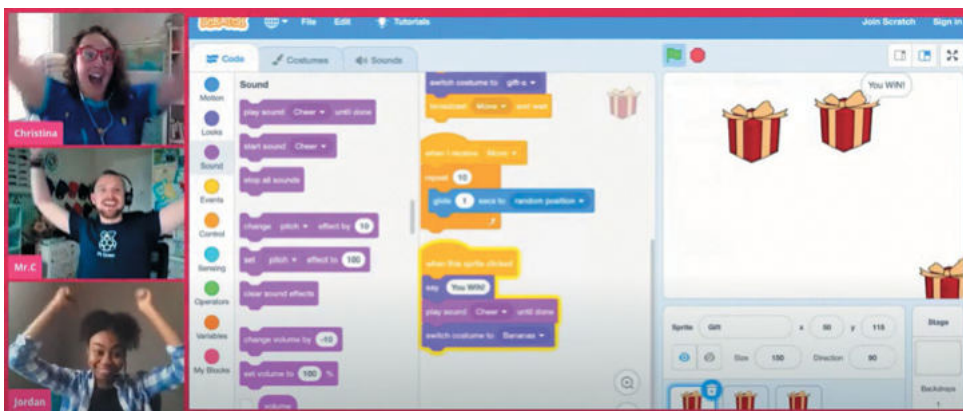
"I'm excited to see where the live stream adventure takes us! "

thought that working at a place named after a fruit would be a poor career decision. Applying to this job was one of the best decisions I ever made.

How did the current Digital Making at Home streams come about?

Digital Making at Home was (and still is!) our response to supporting young people and families staying at home this year. In March, we put together a small (virtual) team to think creatively about what we could do to support the community at this time while we are also staying home. We started with recorded code-along videos and got feedback that folks wanted to interact with us live, so we created the live stream, and I absolutely love how it's evolved to include conversations and coding with people from all over the world!

What other stuff have you done with the Foundation?

Being on the North America team, we're such a small team that we all do a lot to realise the Foundation's mission. So I've done a lot: events, clubs, Picademy, online courses! It's amazing!

Any upcoming plans you can share?

I'm really excited about the work we are doing to prepare for Coolest Projects 2021! Stay tuned for how you can get involved! **M**

▲ Christina and Kevin Johnson help oversee the big USA version of Coolest Projects!

This Month in
Raspberry Pi

MagPi Monday

Amazing projects direct from our Twitter!

Every Monday we ask the question: have you made something with a Raspberry Pi over the weekend? Every Monday, our followers send us amazing photos and videos of the things they've made.

Here's a selection of some of the awesome things we got sent this month – and remember to follow along at the hashtag #MagPiMonday!! **M**

01. Caroline's tutorial on this is coming to a website near you soon

02. Binary clocks are very cool things to make, although we prefer old-fashioned numbers

03. This version of the venerable Tiny 4WD is very nippy

04. We've always liked these style of minimal Raspberry Pi Zero projects

05. This bear is definitely bringing the party everywhere it goes

06. That is a lot of Raspberry Pi 4 boards!

07. Dan's music display project was stumping people online before revealing it was Bowie

08. This is extremely cool, and very DIY

Caroline Dunn
@thecarolinedunn

Replying to @TheMagPi

I worked on a facial recognition tutorial for @tomshardware

01

Werner Venter
@wernerXventer

Replying to @TheMagPi

Binary Clock 🕐

02
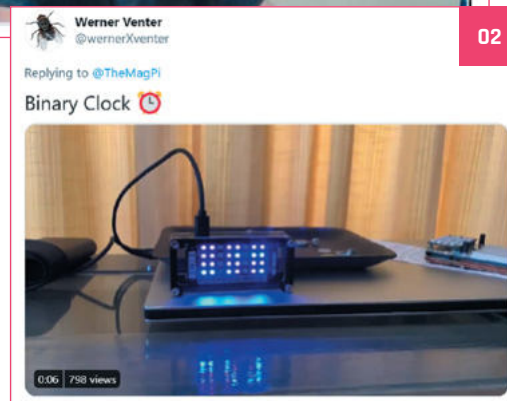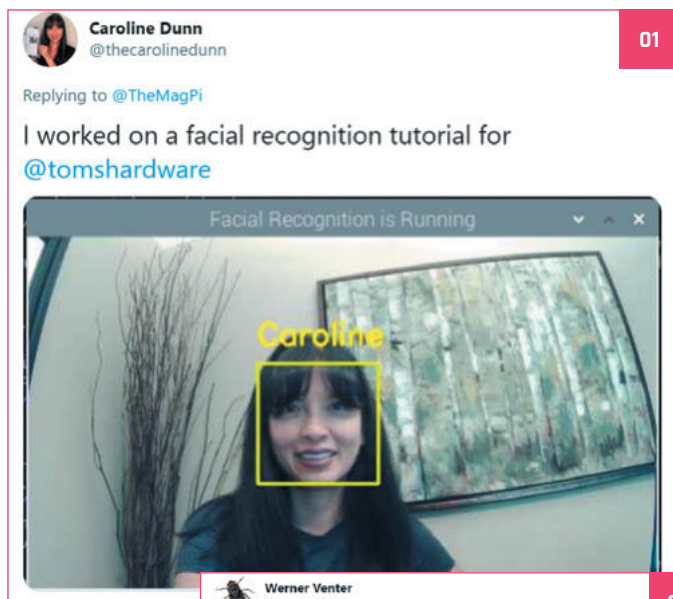
Brian Corteil 🤖
@CannonFodder

03

Replying to @TheMagPi

New robot testing at @cammakespace Monster Truck Tiny 4WD #PiWars

0:05 | 1.2K views

Jamie Bailey
@MrJamieBailey

04

Replying to @TheMagPi

I built a compact, plug-in @Raspberry_Pi Zero display that sits in my kitchen that cycles through some sensor data collected from other Pis in the house. I wrote up the build at medium.com/initial-state/... .

GIF

8 Bits and a Byte
@8BitsandaByte

05

Replying to @TheMagPi

A Pi powered party clock/plane!

Arnaud SAMSON
@_Naviss

06

Replying to @TheMagPi

A 60 pi farm for simulating data from a medical scanner

TeCoEd 📖
@Dan_Aldred

07

Replying to @TheMagPi

I tested Bowie. #DavidBowie @Raspberry_Pi
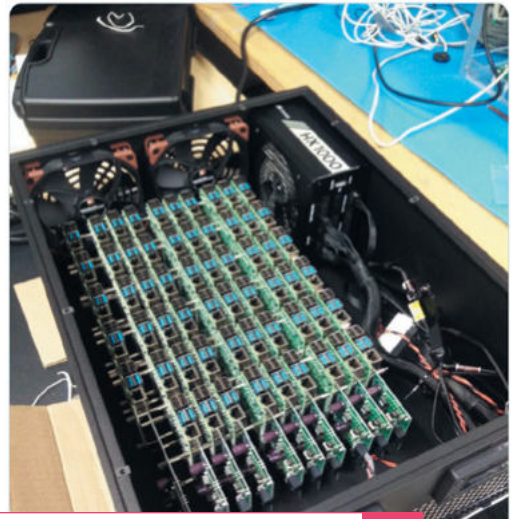
Jeroen Peters
@jeroen_p

08

Replying to @TheMagPi

Sure did! I created the BrachioGraph to let it draw something with three servo motors, two icecream sticks, glue and some wires. It's just a delight to see it in action 😄😄
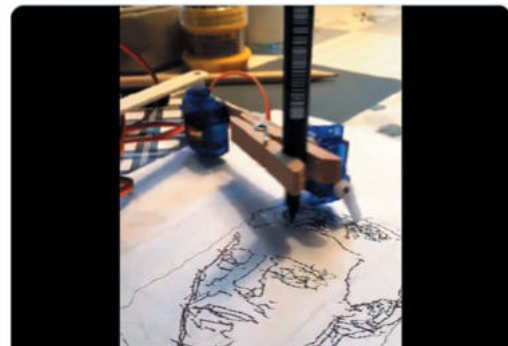
Halloween comes early

The spooky projects are on the rise

At the time of writing, it's a couple of weeks until Halloween. That hasn't stopped folks preparing for the frightful festivities with their own Halloween-themed Raspberry Pi projects. Prepare yourselves for the petrifying projects before you. M

01. We tend to count down to Christmas, but we know a lot of folks prefer the spooky time

02. This box is quite scary, and we hope Brian is (not) putting this out for trick-or-treaters

03. We don't think this was made specifically for Halloween, but it definitely works for it

04. This spooky candy dispenser is perfect while people are maintaining social distance

Scott Young
@thebotmakes

Replying to @TheMagPi

I've updated my Halloween countdown display – now with added bat and scares!

#MagPiMonday
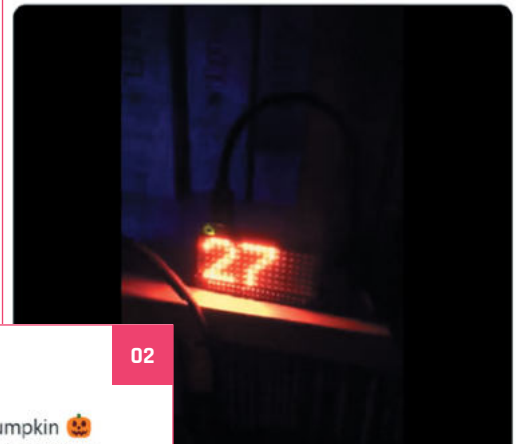
Brian Corteil 🤖
@CannonFodder

Replying to @TheMagPi

Finished the code for my Evil Laugh Pumpkin 🎃 project, just need to paint it black. The brains is a Raspberry Pi Zero, with an Adafruit speaker bonnet, Neopixel bar and a PIR to sense movement. Temped to add a couple of red LEDs as eyes when green.
#MagPiMonday
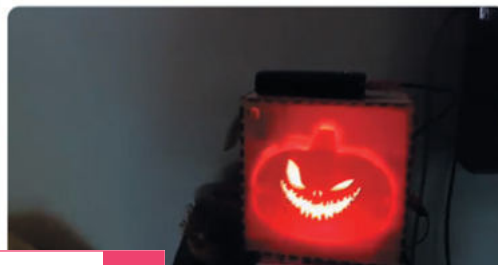
8 Bits and a Byte
@8BitsandaByte

Replying to @TheMagPi

Meet Monty, our Maker Faire Measuring Monster, extra eye included 👁

He captured the atmosphere at @EHVMMF this weekend!

element14 Community
@E14Community

🎃 👻 How can trick or treaters receive candy from different houses on this #Halloween, while staying safe during a pandemic? Watch Adam using a @Raspberry_Pi to create a smart candy dispenser:
bit.ly/3k2oqGN

TRICK-OR-TREATING WITH THIS DIY CANDY DISPENSER

Crowdfund **this!** Raspberry Pi projects you can crowdfund this month

Embedded Learner Board

There are a couple of Raspberry Pi add-ons like this, but nothing quite as striking as this Embedded Learner Board. It's fully funded as of the time of writing and includes a load of pretty cool features like buttons, LEDs, sensors, buzzers, and a 16×2 display. We like it.

▶ kck.st/3ihLlwr

Raspberry Pi 4 Multimedia Case

We always think that the best case for Raspberry Pi isn't always the best case for the job – especially when you want to put it next to other home theatre electronics. This case aims to sit alongside your telly and look smart doing so, with an active fan to cool the system and some nice lights (which can be turned off).

▶ kck.st/2l5sEzr

CROWDFUNDING A PROJECT?

If you've launched a Raspberry Pi-related project, let us know! magpi@raspberrypi.com
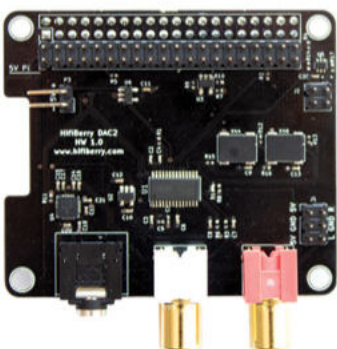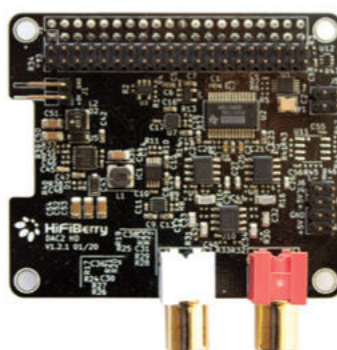
POSSIBLE EVENT CANCELLATIONS

Please follow local public health advice and take decisions on whether to cancel clubs or events in consultation with the venues that host them.

Raspberry Jam
Event Calendar

Find out what community-organised Raspberry Pi-themed events are happening near you...

01. Raspberry Pi STEAM Festival

- Saturday 24 October to Monday 2 November
- Online
- ▶ magpi.cc/AjWfS5

An online festival of Science, Technology, Engineering, Arts, and Maths (STEAM).

02. CoderDojo / Code Club Ireland Virtual Meet-Up

- Wednesday 4 November
- Online
- ▶ magpi.cc/pcUMW7

Monthly informal meet-ups to allow Code Club and CoderDojo communities in Ireland to connect with their peers.

03. Houston Raspberry Pi Meetup

- Wednesday 4 November
- Online
- ▶ magpi.cc/sgL6OZ

A community of coders, artists, educators, and engineers interested in project-based learning with Raspberry Pi.

04. West Sound CoderDojo

- Saturday 7 November
- Online
- ▶ magpi.cc/dNFYcH

Ninjas, parents, mentors, and all are invited to join West Sound CoderDojo for online biweekly sessions.

05. Medway Makers Tech Meetup

- Sunday 8 November
- Online
- ▶ magpi.cc/WKM2wa

Workshops in building cool things with Arduino, how to code for beginners, how to use a Raspberry Pi, and so on.

06. VOID

- Monday 9 to Wednesday 11 November
- Online
- ▶ magpi.cc/US2mG0

A course in reverse-engineering for security researchers and students, which makes use of Raspberry Pi.

07. North Oakland County LabVIEW Users Group

- Wednesday 11 November
- Online
- ▶ magpi.cc/iC7IBC

Application development for Raspberry Pi using LabVIEW, allowing for real-time control.

08. CoderDojo Online

- Saturday 21 November
- Online
- ▶ magpi.cc/X7BMB3

Free children's programming sessions online, presented by CoderDojo Redmond & Bothell.

FULL CALENDAR

Get a full list of upcoming events for November and beyond here:

rpf.io/jam
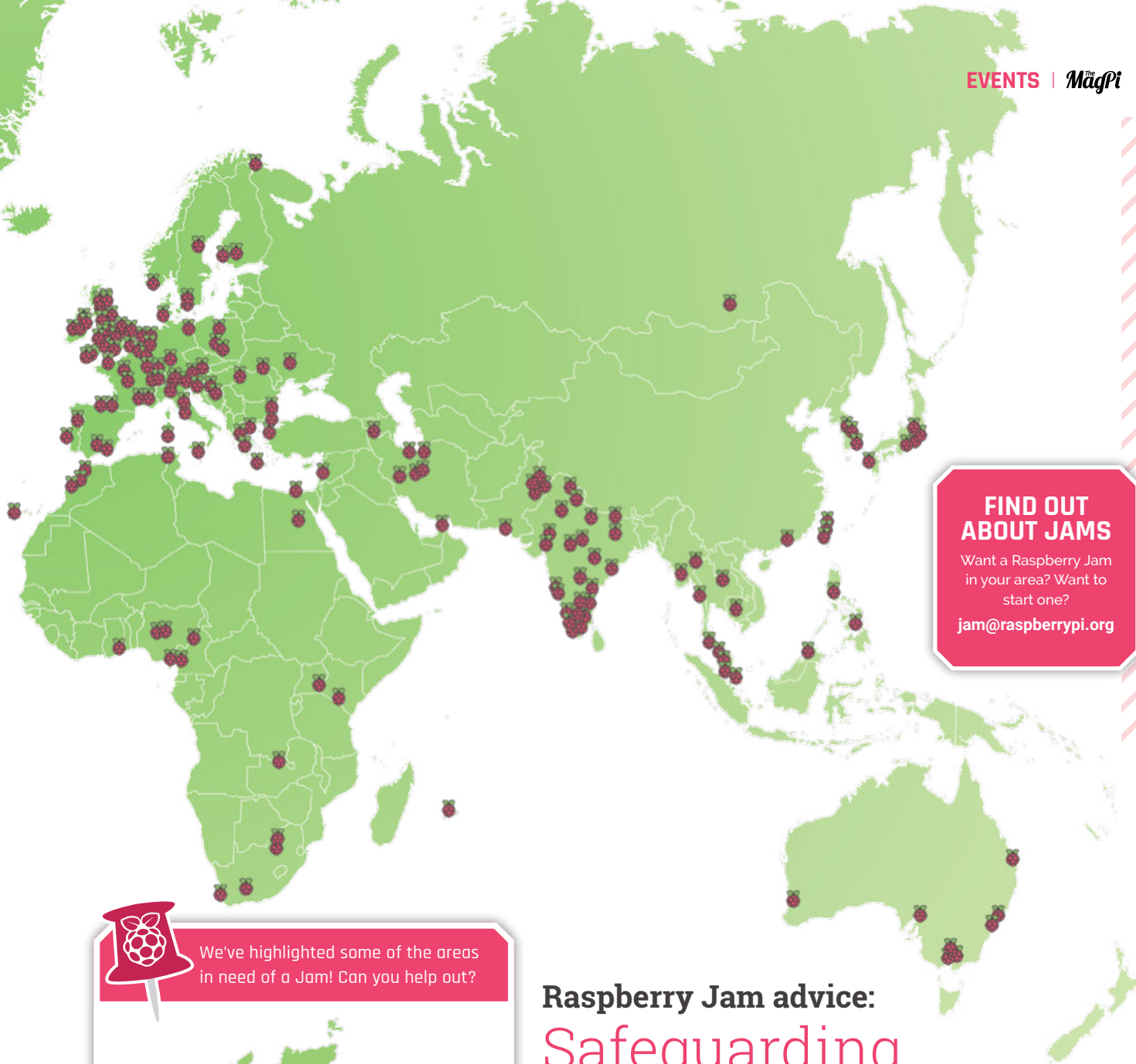
We've highlighted some of the areas in need of a Jam! Can you help out?

Raspberry Jam advice:
Safeguarding

"**A**lthough most of our volunteers are DBS-cleared through other voluntary work, we made a conscious decision that we wanted parents to remain with their children.** The responsible adult does not need their own ticket, but requiring parents or guardians to accompany their children removes the need for DBS paperwork, and means that every child has a familiar authority figure on hand. We also find that children are more focused in the workshops when their parents are around."

Andrew Oakley – Cotswold Jam

Every Raspberry Jam is entitled to apply for a Jam starter kit, which includes magazine issues, printed worksheets, stickers, flyers, and more. Get the book here: **rpf.io/guidebook**

Your Letters
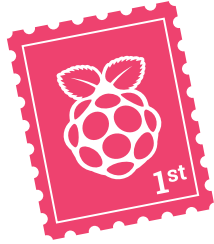
Weather spoons

Haha, that [Weather Station project, *The MagPi* #98 (magpi.cc/98)] is actually quite clever. I've been looking at anemometers for my next IoT project and they're actually quite expensive. I want to make this project more accessible to more people, so I'm going to try this out and test it for outdoor durability.

Torquewrench via twitter

We're fans of it too! Not only is it very practical, but the use of spoons to power the wind meter is a great idea. If you make one for yourself and expand on it more, don't hesitate to contact us so we can try to get it in the magazine in some way!
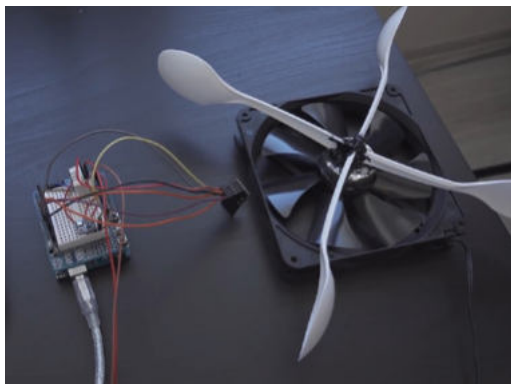
▶ Work with what you have; that's what makers do

USBoot

Since Raspberry Pi 4 came out, I've been waiting for notice that it can boot from USB. I found a number of webpages describing how to do it. Older ones require an SD card for part of the process; now a few show a variety of methods to do this.

I found a very simple way that requires nothing more than my normal SD card image. Here are the steps:

1. Move your SD card from the slot on a Raspberry Pi into a USB card reader plugged into a Raspberry Pi USB slot and turn it on. That's the only step I needed in a Raspberry Pi 4; it boots as normal and proves it works.

2. When ready, I use my normal imaging tool (Win32DiskImager) to copy that image onto a USB drive of my choice to make it permanent. I've built [Raspberry] Pi clusters the same way, so if it doesn't work, you've made a mistake.

David via email

That's a very simple solution! You can also boot from the microSD card as usual, connect your USB drive to Raspberry Pi and use SD Card Copier to copy your microSD card to the USB drive. Be sure to select the 'new Partition UUIDs' option. We are testing USB drives and our speed results have been mixed. Let us know how you get on.

▼ Get all nostalgic about the 1980s with BeePi, an OS emulating the Atari ST

Emulation

I've been hugely enjoying the legal game emulation series by K.G. Orphanides. Please thank them for taking the time to discover emulation of console games and homebrew!

Jo via Facebook

We're glad you're enjoying it and we've let K.G. know about your kind comments. We'll keep doing these pieces as long as K.G. has wisdom to give us, so look forward to more in the future.

We'd also like to remind folks that there are a load of old Mega Drive ROMs that Sega itself sells over at Steam. Recently, Sonic the Hedgehog 2 was given away for free, but it's usually $5/£4, and others vary in price as well. Take a look over there and rediscover an old fave!

Atari Pi

If anyone was ever a fan of Atari ST computers, maybe this [BeePi emulated OS] would be of interest and maybe an excuse for an article in *The MagPi*? Latest version released yesterday after a two years gap. Downloading it now and will give it a spin later tonight: magpi.cc/beepi.

Martin via email

Ooh, that looks very cool – definitely sure several of our readers will be interested in that! It's a specific build of Raspberry Pi OS with some emulators for the older Atari computers. We've explored emulating retro computers before, so if you're looking for software to run on it, check out those features in *The MagPi* #88 (**magpi.cc/88**) and #67 (**magpi.cc/67**).

▲ Sega is better than others about game preservation

Contact us!

> Twitter   **@TheMagPi**
> Facebook   **magpi.cc/facebook**
> Email   **magpi@raspberrypi.com**
> Online   **raspberrypi.org/forums**

WIN ONE OF THREE
PIBOY DMG
FULL KITS

In the last issue of *The MagPi* (**magpi.cc/98**) we gave the PiBoy DMG a highly coveted 10/10 – now's your chance to get one of these amazing kits.

" PiBoy DMG is a complete handheld gaming system powered by a Raspberry Pi. PiBoy is compatible with Raspberry Pi 4B, 3B, or Zero. With the Raspberry Pi 4, take emulation to the next level. "

Head here to enter: magpi.cc/win | Learn more: magpi.cc/piboydmg

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NVIDIA
NAILS IT
FULL REVIEW OF THE GEFORCE RTX 3080

1 4K GAMING AT OVER 200FPS

2 RAY TRACING COMES OF AGE

3 LEAVES RTX 2080 Ti IN THE DUST

+ **DEEP DIVE** HOW NVIDIA'S NEW GPU ARCHITECTURE WORKS

RTX 3080

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100

RASPBERRY PI
MOMENTS

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Plus!

Get started with GUIs

Build a handheld retro console

Make a Santa's Run Christmas project

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Let's go shopping

Lucy remembers a former life in retail and thinks
now is a good time to go on a little spree

Like lots of kids from the nineties, I grew up working in retail. It's not always an easy job, but on the right day it can be a lot of fun.

The unwashed masses are routinely entertaining, and working in a shop taught me how to interact with people.

" The Raspberry Pi store is a wonderful place to visit "

I remember with fondness the blind kid who played video games with his mates; the dad who treated his son to a new NES game every month even though he could get it cheaper over the phone; the Christmas where Telstar's Foster and Allen video was on a constant loop; the summer of the *Teenage Mutant Ninja Turtles* theme tune on a loop that very nearly sent us mad.

I once sold an Amiga game to Barry Chuckle and did not say "to me to

you" when I handed it over. My niece worked in a health shop, and had a regular who was a Gothic vampire that liked to walk in triangles.

If you've never done retail, I feel for you. It's great fun!

Ask an expert

Retail workers typically work in an area they enjoy, and they often know a lot about their subject. Retail can springboard you into a career in an area you love. Whether it's in computing, rock climbing, health, or haute couture.

The Raspberry Pi Store in Cambridge (**magpi.cc/retailstore**) is a wonderful place to visit. It's open seven days a week on the first floor of the Grand Arcade. Staffed by people who love Raspberry Pi, it's full of interactive demonstrations. There's an amazing range of products to buy. Everything from Raspberry Pi computers, to code-teaching board games, electronics components, and serious hardware. Where else can you buy a soldering iron and a Raspberry Pi novelty t-shirt?

Consuming isn't the be-all-and-end-all of modern life. Making is a much more soul-rewarding process, and we often espouse the joys of a good build.

But the two go hand-in-hand. Making requires raw materials and you'll need to buy your kit from somewhere.

Throughout this magazine, you'll find references to some of the great Raspberry Pi stores and resellers. These folks are the backbone of the Raspberry Pi community. Now is a good time to help them out.
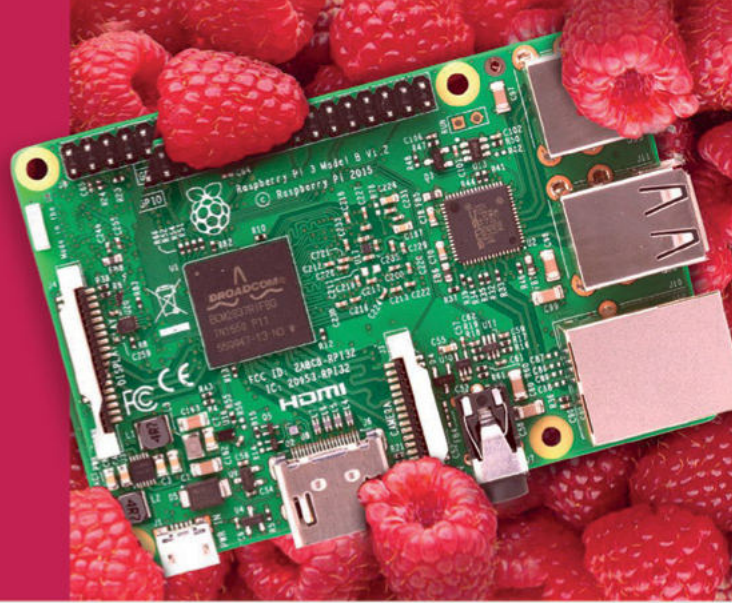
So, as the winter nights draw in and the weather takes a turn for the worse, take a look at our Raspberry Pi Ultimate Wishlist (page 41) and think about what you can make with a Raspberry Pi computer. Then go help one of the stores out. M

AUTHOR

Lucy Hattersley

Lucy briefly worked in Just Micro and can visit her old store in Jack The Nipper on the Spectrum anytime.

@lucyhattersley